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ON THE NECESSITY OF FURTHER RESEARCHES ON THE MILKY WAY.

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For Popular Astronomy.

As there is a tendency to restrict the working field on which amateur astronomers may make themselves useful to science, it is, perhaps, a matter of some importance to point out a subject which affords an excellent opportunity and for which no instrument whatever is required; nothing indeed except a pair of rather sharp eyes and a sky of tolerable clearness, viz., observations of the Milky Way with the naked eye.

All accurate drawings of the Milky Way are comparatively modern. It is true that Ptolemy (130 B. C.) had already recognized its invariability as a whole, and he has given a rather careful description of it in his Almagest; Easton in his historical review of the drawings and descriptions of the Milky Way remarks that Ptolemy's description is certainly superior to all the rather fantastic representations given in the maps published before the last quarter of our century.

But up to 1867 no serious attempt at a study of the northern part of the Milky Way seems to have been undertaken; and this is the more astonishing because Sir John Herschel had published his admirable observations of the southern portion as early as 1847. Argelander in Germany and Lassell and Mark in England endeavored, for many years in vain, to direct the attention of amateurs to this neglected branch of astronomical research. In 1867 Dr. Klein in Colonia, (Cologne,?) published the first part of a very remarkable description of the northern Milky Way, but he has not been able to bring it to a conclusion. Edward Heis was the first to undertake for the northern hemisphere what Sir John Herschel had already done for the southern part of the Milky Way. In Heis's maps the absence of detail is however conspicuous; as is still more the case with the maps of Houseau, which were constructed at Jamaica and contain both hemispheres. Therefore it was very satisfactory to receive the admirable drawings of Dr. Boeddicker, who, observing at the Earl of Rosse's Observatory at Birr Castle, was able to publish his atlas of the northern Milky Way in 1892.

One might think the question settled by Dr. Boeddicker's publication, and that the drawings executed in Lord Rosse's Observatory completed, by far more detail, the sketch made by Dr. Heis. On comparing Boeddicker's with that of Weis however more discrepancies are shown between these two, than was ever the case with the drawings of other celestial objects; it seemed as if they had nothing in common. Where Boeddicker's maps revealed the existence of numerous streams; dark spots were visible in that of Heis, and the contrary happened also. In certain parts the two drawings seem to represent wholly different objects; it is true that in a few places the same features may be detected in both drawings.

Now it is clear that no real changes of such importance and extent can have occurred in the Milky Way in so short a time. Nor can inability of one of these observers account for such differences. Boeddicker had already a very good name as a delineator of nebulae and planets, and that Heis was gifted by nature with exceptionally sharp eyes needs not to be dwelt upon. And still we might be inclined to believe, that, the delineation of the Milky Way being after all a matter of secondary importance for Heis, and his engraver and printer having executed their task certainly not to his own contentment, the discrepancies were due to one of the observers—if there had not been the fact that the drawings of Trouvelot and Houseau presented also considerable differences between them and the drawings of Boeddicker and Heis. Moreover a perfectly independent series of observations were made about the same time by Easton, and his maps, though offering in some points a remarkable agreement with those of Boeddicker, show in so many instances a totally deviating structure, that it seems very difficult to decide between two observers who have both spent considerable skill, patience and time upon the matter. I may perhaps add that I have myself laid down a great many observations in a drawing which was exhibited at the October meeting 1893 of the "Vereinegung für Freunde der Astronomie und Kosmischen Physik" and that this drawing also presents many differences from the maps of Boeddicker as well as those of Easton.

And it is not merely differences in detail of structure, but many characteristic features of the Milky Way are shown in two or three drawings but are absent in the fourth. For instance the conspicuous patch of luminosity between β and γ Cygni is somewhat difficult to trace on Dr. Boeddicker's maps—as are indeed all the great divisions in Aquila and Cygnus, owing

to the abundance of detail—but the drawings of Heis and Easton show it at the first glance, though they give less detail here and there. The intensities of the various parts of the Milky Way in Cassiopeia, as represented in Boeddicker's maps do certainly not agree with the distribution of luminosity in that part of the heavens; on the other hand, Easton's drawings fail to show the offsets and outlying branches in several parts of the girdle; particularly those in Draco, seen by Heis and confirmed by Boeddicker. These examples could easily be added to insist upon the fact that the discrepancies do not concern mere trifles, but often the main points.

There may be two explanations of these extensive divergences between the existing drawings of the Milky Way. They may be the consequence of the different methods employed by the observers, their unequal skill and experience, but it may also be that the character of the galactic phenomenon precludes its being fixed by delineation. This was the opinion of Professor E. E. Barnard in 1890: "It is only necessary," he said, "to mention the very great differences in delineation of even the more conspicuous parts of the Milky Way, as shown on different star charts, to see, that we have not the means in such charts to make anything like a comprehensive study of the Milky Way. Eyes differ so much and astronomers as a rule are such very poor artists, that we may never expect to get anything like a fair delineation of the Milky Way by the human hand alone." This was written, however, before the publication of Easton's and Boeddicker's drawings, which, though they give a very different representation of some parts of the Milky Way, show in other parts a fair resemblance even of detail. Moreover Mr. Easton communicated to me, some time ago, a letter from one of his correspondents, showing a very remarkable agreement in the results of two independent observers in detail, as minute as the dark spot about η Cygni and the curve limiting to the east the brilliant region between ρ and π' Cygni, both distinctly visible in Easton's and Boeddicker's maps. Besides, as it is evident that the difference between the visual power of the observers can have but a slight effect on the delineation of the greater masses of the galactic luminosity and as the remaining disturbing causes manifestly do not prevent a remarkable agreement even in detail, we must look elsewhere for the true explanation of the discrepancies in the drawings now available. I am convinced that these discrepances may be satisfactorily accounted for by the great differences in style (method of drawing) and by the difficulties adherent as well to this kind of observations as to an adequate publication of the results.

Plassmann, the well known observer of variable stars, has already pointed out how much the subjectivity of the delineator influences the result of his observations. Houseau, for instance, shows a tendency to represent the conspicuous patches of luminosity in the form of ellipses or shields; in Heis' drawings we see a sort of mosaic-work; Trouvelot has indistinct wadded patches; in Boeddicker's drawings the revealing of narrow strips and streams is manifest; Easton has a succession of broader streams and patches of luminosity. In an object so difficult to lay down in a drawing, this method of the observer must have a very great influence on the general aspect of the drawing. Then we have to deal with the slightly different aims of the observer; Houseau endeavored to follow his "isophotic lines," Boeddicker searched after as many details as his eye was able to detect, Easton seems to have had in view the graduation of the intensity of the greater masses. It is obvious that much depends on the particularity whether the spaces between the luminous patches are more or less filled in.

Next we have the difficulties resulting from difference of scale, the errors unavoidable in printing and publishing the maps, the intervention of the engraver, and so many additional causes of error of every kind.

But the influence of all these causes of error may be greatly diminished by the co-operation of many persons with a certain ability of observing and much good will for the sake of science. It would be superfluous, I think, to explain that a representation as true as possible of the whole girdle of the Milky Way by drawing and description, is greatly needed, even now that photography has given a series of representations of somewhat different nature. Not only will it afford an opportunity to posterity to find out variations, when they should occur, but now also it will be of much value in researches about the structure of the universe. "The results," obtained by the Herschels, by Struve, Proctor and Easton, while they had much more imperfect materials to deal with, show what may be expected from a better knowledge of the Milky Way. There is a useful field of work open to enthusiasts. As Mr. W. H. Wesley wrote after the publication of Easton's drawings: "It is much to be desired that others may undertake the very difficult task of delineating independently the naked eye appearance of the Milky Way. It can only be by the accumulation of independent drawings, that personality can be eliminated and a representation obtained sufficiently certain and satisfactory to be used with confidence in the future discussion of possible changes."

In a following article I will describe the new charts which Mr. Easton has provided after the catalogue of Marth for the use of observers who will take up this line of research, and the best methods to use for this purpose.

THE STUDY OF THE VARIABLE STARS. IX.

PAUL S. YENDELL.

For Popular Astronomy.

ALGOL. 4.

In the third of my papers on Algol, at the head of page 307 of the current volume of this periodical, I have made a statement of the hypothesis known as Tisserand's, which is incorrect, having at the time never seen Tisserand's original paper. Since that article was printed, I have had opportunity to examine the communication, and a brief abstract of and comment upon it are a part of the purpose of this supplementary paper.

In the second part of Chandler's paper, quoted on p. 306 (*Astronomical Journal*, Vol. XI, p. 121) occurs the following statement:

"Whatever the nature of the pure elliptic motion, the times of conjunction must follow each other at exactly equal periods, unless (*a*), one or both components are not spherical; or unless (*b*), there is at least one more body in the system. While by (*a*), inequalities in the times of conjunction would necessarily result, this hypothesis seems to be insufficient, since it would be inadequate to explain the character and magnitude of the observed irregularities; and it could not account for the observed variations in the place." So that the original suggestion of the idea came from Chandler.

What Tisserand did was to re-examine Chandler's first reason, and show that a moderate flattening of one or both components of the system would account for the phenomena, if the orbit of the satellite were not circular.

Tisserand's communication appeared 1895, Jan. 21, in the *Comptes Rendus*, Vol. CXX, p. 125. After stating Chandler's theory and formula (see my paper above cited, p. 303), he goes on to say:

"He" (Chandler) "has sought to demonstrate the reality of this orbit by the variations in Algol's proper motion. But the proof of this displacement is difficult; in fact, it rests upon the

very delicate comparison of the various star-catalogues, and Bauschinger, reopening the question quite recently (*Vierteljahrsschrift der Astronomischen Gesellschaft*, 29th year), arrives at the conclusion that the irregularities in Algol's proper motion do not exist.

Supposing this critique decisive, we must look for another cause of the inequality. I think it can be very simply explained by admitting the existence of a single dark satellite, the ellipticity of its orbit, and a slight flattening of the principal body." . . .

He proceeds to show, at too great length to be quoted here, that the eccentricity of the orbit would be not far from 1/8; that on the assumption that Algol is homogeneous, only a moderate flattening, comparable to that of the Earth, is called for; and that the duration of the eclipse should increase by $1^h.63$ from the year 1800 to 1864, the mean epochs of Wurm and Schönfeld. "Now, the first of these astronomers gives this value as $6^h.5$, and the second as $9^h.0$; the observed variation accords fairly well with the computed, which goes to confirm our hypothesis."

With regard to the above confirmation, it appears to me that this difference may be more apparent than real. Wurm's observations were made many years before the far more accurate method of comparative estimates employed by Schönfeld was put in use, and I very much doubt if he could recognize an interval of, say, two steps, by any of the methods then in use.

A reference to Schönfeld's table of readings from his mean light-curve shows that at the beginning of the eclipse the star was at that epoch an hour and a half in decreasing by two steps, and at the end occupied an hour and a quarter in increasing by the same amount; it will be seen that the sum of the two accounts for the entire difference between Wurm's and Schönfeld's values for the duration of the eclipse, and in view of the crudeness of the methods of observation probably used by the former, renders this apparent difference of very little significance, so that the question, so far as this evidence goes, still remains in abeyance, and it is very desirable that the methods of Schönfeld and his successors should now be applied to the case.

In all Tisserand's article, however, there is no question outside of Chandler's hypothesis (*b*) of a third body.

To sum up: Chandler's hypothesis (*a*), which Tisserand has developed and shown that it cannot be excluded (unless the irregularity of proper motion actually exists), depends essentially upon the assumption of polar compression, while hypothesis (*b*) depends essentially on a third body. The choice between the two will be ultimately;

(1st) in favor of (*a*), if the alleged apparent irregularity of proper motion on the face of the sky is found not to exist;

(2d) in favor of (*b*), necessarily, if this motion is real.

In this connection, the paper published in the *Astronomical Journal*, Vol. XV, p. 49, by Prof. Lewis Boss, of the Dudley Observatory, is of extreme interest and importance.

In view of the indications found by Professor Boss, it is of interest to note his statement; "In order to save labor, I have made use of Dr. Bauchinger's tables (*VJS* XXIX, p. 216–220)." It is also interesting to compare his findings, as stated below, with those of Dr. Bauschinger, above quoted.

On pp. 51 and 52 he gives tables for 1875 of the corrected seconds of R. A. and Decl. for each catalogue place, from Bradley (1754), to Albany (1895), with residuals both on the supposition that the proper motion is rectilinear, and upon the assumption that a part of the proper motion in each coördinate depends upon the sine and cosine terms having a period of 130.91 years.

Summing up on p. 52, he finds;

"That on the assumption of rectilinear motion the probable errors of the units of weight are $\pm 0^s.037$ and $\pm 0''.37$ respectively. . . .

Under the second supposition, involving periodic terms in the expression of proper motion, ... the respective probable errors of the units of weight are $\pm 0^s.036$ and $\pm 0''.35$. . . . . .

In right ascension the coefficient of the inequality is three times its probable error; and in declination, it is more than four times the probable error. Leaving entirely out of the account considerations based upon the behavior of *Algol* as a variable star, the degree of mathematical probability in favor of the assumption, that the foregoing results represent an actual inequality in the proper motion, must be set over against the *a priori* presumption against the reality of variable proper motion for any given star. The discussion of this point in the present state of our knowledge could lead to no precise result.

Taking the result of this computation apart from any other consideration, I venture the opinion, however, that there is a preponderance of probability in favor of the real existence of a periodic element in the proper motion of *Algol*. Were this star of the fourth magnitude instead of the second, I should not hesitate to say that this preponderance is large.

Let us now consider the foregoing numerical results in connection with the observations of *Algol* as a variable star. Suppos-

ing the periodic terms to be real, they indicate that the apparent motion of the star is an ellipse. The position-angle of the northern end of the major axis is 34°; the semi-axis major is 0″.522 ± 0″.103, and the semi-minor, 0″.224; the inclination of the real orbit to our line of sight under the hypothesis of circular motion is 23°. Under the fundamental hypothesis, *Algol* would have passed through the plane perpendicular to the line of sight at the centre of gravity of the hypothetical system in 1808 ± 4y.5. . . . . The coincidence of these dates computed from two entirely distinct sources of evidence (except for the assumption of the period of 130.91 years in common) appears to me as significant as it certainly was unforeseen. We may summarize the state of the case thus. The foregoing computation indicates that *Algol* revolves in an orbit of which the maximum calculated radius is five times its probable error; and the same computation indicates that the star passed the major axis of its apparent orbit within three or four years from the most probable date derived from the observations of Algol as a variable star."

This is the state of the evidence up to this time, so far as it is known to me. Although not amounting to positive proof of Chandler's hypothesis, it makes the presumption appear very strong in its favor. Still the theory cannot be regarded as proved, unless supported by the next ten or twenty years' observations. In the mean time, the duration of the eclipse should be the object of careful and persistent observation, and it is earnestly hoped that some of our observers will be induced to take up and follow the watch on this star.

In the previous paper, as printed, there are two errors in the notes to the list of Algol stars at the end, which should be noted, as follows: Page 308, top of page; Number 5374 should be 5144, as the note applies to Y Bootis, not to Delta Libræ.

6442; for "derive," read "observe."

OTES RELATING TO MATHEMATICAL SYMBOLS.

HERMAN S. DAVIS.

For Popular Astronomy.

It is perhaps seldom that mathematicians and astronomers, who daily avail themselves of the labor-saving artifices of "mathematical shorthand," really pause in their work to think of the utility and the origin of those signs and symbols which so

greatly facilitate concise reasoning and a rapid flow of thought.

A treatise having for its subject "The History of Mathematical Symbols," compiled with completeness and accuracy, would be very interesting from a typographical, a bibliographical, and a mathematical point of view.

Such a treatise should begin with a history of the adoption of the Arabic numerals. It should then give the date when each symbol or device was first used—in what book, and where published. It should show both the typographical and the historical development of that symbol at subsequent dates down to its present form and use. All this should be accompanied by the needful notes, quotations, and references to authorities.

That no such book exists in any language, so far as I have been able to ascertain, would leave to its author the possibility of showing original research through a wide range of literature, and a personality in the treatment that ought to be attractive to some one of antiquarian tendencies. It is not often that one has so good a chance to produce a work that would be so very unique as this picture of the origin and development of mathematical nomenclature.

Without the intention of compiling such a work, I have, nevertheless, in the course of my reading, jotted down memoranda bearing upon this subject. As even these, in spite of their meagreness, may not be devoid of interest I give here a summary of the information thus obtained and the source.

The following books will be referred to by their number and the page: thus avoiding frequent repetition of their titles.

36. Introduction to the Literature of Europe in the XV, XVI and XVII centuries, by Henry Hallam. One volume edition, by Ward, Lock & Co., London.
84. History of the Inductive Sciences, from the earliest to the present time, by William Whewell. Vol. I. Third edition. Appleton & Co., New York, 1888.
96. Histoire de l'Astronomie Ancienne; par M. Delambre. Tome I. Paris, 1817.
100. Histoire de l'Astronomie Moderne; par M. Delambre. Tome II. Paris, 1821.
121. Histoire de l'Astronomie Ancienne, par M. Bailly. Paris, 1775.
417. Encyclopedia Britannica, Volume XVII, article "Napier."
475. Geschichte der Astronomie von Rudolf Wolf. Munich, 1877.
491. Histoire des Mathematiques, par M. Montucla. Tome I. Paris, 1758.
541. An Historical Account of the Origin and Progress of Astronomy, by John Narrien. London 1850.
577. Annuaire de l'Observatoire Royal de Bruxelles, pour 1880, 1881, 1882.

That our characters for the numerals are of Indian source, transmitted by the Saracens to Europe through Gerbert (Pope Sylvester II) who studied in Spain in the beginning of the tenth century, see 96:518 and 475:107 and 491:360-365 and almost any other history of mathematics or of astronomy; also 36:55.

The very first evidence of the introduction of these numerals into public documents in *England* is the appearance of the single figure 3 in a public record in the year 1282. See 36:56.

Logarithms to simplify the use of these characters in certain computations were invented by the Englishman, Napier, and first published in 1614. See 417:184 and 36:645 and many other books.

Napier seems to have been the first mathematician who fully appreciated that a negative quantity is "something less than nothing," and he called positive quantities "abundantes" and negative quantities, "defectivæ." To the former he gave the sign + and to the latter the sign —. 417:184. Napier, however, was not the man who invented these signs. That honor is due to Michael Stifel (1487-1567) professor of mathematics at the University of Jena, who published them in 1544 in his *Arithmetica integra*. See 36:385. The writer of the article in the Brussels *Annuaire* pour 1880, page 127, attributes their first appearance to Leonardo da Vinci "at the end of the fifteenth century." Peletier (1517-1582) in his treatise on algebra published in 1554 does not use the + and — signs, but uses *p* and *m* instead. See 36:385.

As early as 1489, in a book published by John Widman, the + and — symbols had been used, but with a significance different from that now usually attached to them. They were used by him in division to indicate that the quotient was slightly in excess or in default of the true result. See 577 pour 1880:128.

The radical sign $\surd$ to indicate the extraction of a root was invented by Peletier, who has been already mentioned here. See 36:385. There is some authority for the statement, however, that this character was first published by Christopher Rudolph in 1524. See 577 pour 1880:129: where it is also stated that + aud — were used by Rudolph in this same year.

The sign of equality = was invented by Robert Record, a physician of London, who, in a treatise on algebra which he called the *Whetstone of Wit*, quaintly remarked that "to avoid the tedious repetition of the words 'is equal to,' I will set, as I do often in work use, a pair of parallels, *gemowe* lines of one length thus =, because no two things can be more equal." This book was printed in 1557, one year before the author's death. See 36:385 and 577 pour 1880:130. Vieta (1540-1603), probably at a date later than Record's book, used this same sign = but for quite a different purpose. With Vieta it had the significance of our present $\pm$ indicating that a proposition was true both of + and of —. See 36:388.

The superior figure written after a number to denote the power to which that number is to be raised was introduced by Stifel in 1544. See 577 pour 1880:129–130.

The decimal point, though such a marvel of simplicity, has been one of the most useful of all the devices of abbreviation. It was introduced by Napier in 1619. For an account of this and of previous devices which had been used to the same end, see 417: 185. The same reference informs us that expressing fractions as decimals was introduced by Stevinus (1548–1620), a book-keeper in Antwerp, in his tract *La Disme*, published in 1585.

In early times, the mathematicians of India had developed a sort of algebra in which they used *colors* to denote the unknown quantities. Thus, assuming modern signs, an equation might have been written, 3blue + 4white — 7black = 6, etc. See 96 : 554. In Europe alphabetical characters were not at first employed, except that the *Res*, or "thing" to be obtained was sometimes set down as R. for the sake of brevity. Stifel, in 1544, first employed a literal notation, A. B. C. to express unknown quantities; while Cardan and others occasionally made use of letters to express indefinite numbers: but Vieta first applied them as general symbols of quantity. See 36:386.

Trigonometry, like geometry, may have had its origin in Egypt; but the Greeks undoubtedly reduced its concepts to a more scientific form, and it has been transmitted to us from the Greeks by the Arabs, who during the Dark Ages were the sole depositaries of the learning of the ancients. In the course of transmission it received, however, a number of improvements: one of these was the substitution of the sine for the chord. 491:358 and 36:78. "The most probable origin of the word *sine* appears to be that *sinus* is the Latin translation of the Arabic word *gib*, which signifies a fold, the two halves of the chord being conceived to be folded together." The sine was first used by Albategnius (877?–929). See 84:181. In a *Translation of the Surya-Siddhanta* by Ebenezer Burgess, reprinted from the *Journal of the American Oriental Society*, at New Haven in 1860, on page 56 is the claim that sines had, long previous to the time of Albategnius, been used by the Hindus. In 491:xxxiii and in 577 pour 1881:194 the origin of the word sines is that being the half-chords they were in Latin called *semisses inscriptarum*, the full chord being called *inscriptæ*. Thence arose the abbreviation, S. Ins., which subsequently by abuse became *sinus*.

Tangents had long been used in India, Egypt, Greece and elsewhere, being nothing more than the "shadows" cast by the

gnomons. 475:120 and 541:292. But it seems we are indebted to Abul Wefa (939–998) for their introduction into trigonometry as an abstract concept for general computation. 577 pour 1881:195. This same reference gives to Abul Wefa credit also for the *secant*, but states that the *words*, tangent and secant, were introduced by Fink in 1583. In 100:34 Delambre gives credit for the introduction of *secants* to Rheticus (1514–1576).

It was the Arab, Geber, who first marked the importance of the complementary functions, and who made use of the cosine which he designated as the "sine of the complement." Thus arose the abbreviation *co.* which was first found in a book by Oughtred printed in 1657, where it was put after the function to which it belonged, thus *sco* stood for cosine, etc. It was in this same book that the symbols *sin a*, *tan b*, etc., were introduced instead of the periphrases common hitherto. Oughtred had used that symbolism for thirty years previous to its publication; and this leads me to remark that doubtless if manuscripts, such as private memoranda and notes, were examined by one composing such a book as I have proposed on the history of signs, it might be found that many symbols and abbreviations were used which did not find their way into published works until much later dates on account of typographical difficulties. See 577 pour 1881:196.

It seems to have been Grienberger (1561–1636) who first conceived and executed the idea of shortening trigonometrical tables by a half, by turning the functions back at 45° and putting the argument at the bottom of the page. 577 pour 1881:197.

In astronomy the origin of the symbols for the signs of the zodiac is of considerable interest. 121:514. The origin of the symbols for the Sun, Moon and planets is given in 577 pour 1882:197. The characters now used to denote the *nodes* of the Moon's orbit ☊ ☋ are reminders of the time when these points were called the "head" and the "tail" of the dragon (by which name they are known even at the present day among compositors in the printing offices). 121:514.

The above notes are given without any attempt on my part to verify the accuracy of statements made in the authorities quoted; of course that should be done by anyone writing the history proposed. Moreover the facts here presented are but the slightest indication of the vast mass of facts that may be gathered upon this subject by one who has the taste for delving in ancient lore, and I hope this article may incite some one to the task.

COLUMBIA UNIVERSITY OBSERVATORY,
New York City, Nov. 8, 1897.

THE PROBLEM OF THREE BODIES.

F. R. MOULTON.

FOR POPULAR ASTRONOMY.

The most famous problem of astronomy is to determine for all time the motion of three free bodies in space, mutually acting upon each other according to Newton's Law of Gravitation. Nearly all of the world's most celebrated mathematicians, from Newton to Poincaré, have made it the subject of profound memoirs. It will be the object of this paper to state in popular language what progress has been made in the solution of this problem.

The discoverer of the law of gravitation completely solved the problem of two bodies in the Principia. That is, if the positions, masses and motions of two perfectly free bodies were given, he showed how the positions at any other time, past or future, could be determined. Under the law of attraction varying inversely as the square of the distance he found that the bodies would forever describe conic sections around each other, and that each would be in the focus of the conic section of the other. Besides this the law of proportional areas holds true. Thus, with the shape of the orbit known, and the rate at which it is described, it can easily be inferred that the position of the body can be found at any time, when the initial data are given.

Naturally after the problem of two bodies, the problem of three bodies would be the next to be attacked, as presenting fewer difficulties than where a larger number are involved. To this Newton found only a very approximate solution. His methods were geometrical, yet so refined and ingenious that they have scarcely been improved to this day. Indeed it is doubtful if any other man has ever lived who had so great a command of synthetic geometry. His work was especially adapted to the motion of the Moon in the system of the Sun, Earth and Moon. His tables agreed fairly well with the observations of his times; but the immensely more refined measures of modern observers have required a corresponding improvement in the theory. This has been largely accomplished by French astronomers, who, abandoning geometry, have turned their attention to methods of analysis.

The problem stated in the notation of the differential calculus is as follows, where m_1, m_2 and m_3 are the three bodies and x_1, y_1, z_1; x_2, y_2 z_2 and x_3, y_3, z_3 their respective coördinates.

$$m_1 \frac{d^2 x_1}{dt^2} = -\frac{k^2 m_1 m_2 (x_2 - x_1)}{r_{12}^3} - \frac{k^2 m_1 m_3 (x_3 - x_1)}{r_{13}^3}$$

$$m_1 \frac{d^2 y_1}{dt^2} = -\frac{k^2 m_1 m_2 (y_2 - y_1)}{r_{12}^3} - \frac{k^2 m_1 m_3 (y_3 - y_1)}{r_{13}^3}$$

$$m_1 \frac{d^2 z_1}{dt^2} = -\frac{k^2 m_1 m_2 (z_2 - z_1)}{r_{12}^3} - \frac{k^2 m_1 m_3 (z_3 - z_1)}{r_{13}^3}$$

$$m_2 \frac{d^2 x_2}{dt^2} = -\frac{k^2 m_2 m_1 (x_1 - x_2)}{r_{21}^3} - \frac{k^2 m_2 m_3 (x_3 - x_2)}{r_{23}^3}$$

$$m_2 \frac{d^2 y_2}{dt^2} = -\frac{k^2 m_2 m_1 (y_1 - y_2)}{r_{21}^3} - \frac{k^2 m_2 m_3 (y_3 - y_2)}{r_{23}^3}$$

$$m_2 \frac{d^2 z_2}{dt^2} = -\frac{k^2 m_2 m_1 (z_1 - z_2)}{r_{21}^3} - \frac{k^2 m_2 m_3 (z_3 - z_2)}{r_{23}^3}$$

$$m_3 \frac{d^2 x_3}{dt^2} = -\frac{k^2 m_3 m_1 (x_1 - x_3)}{r_{31}^3} - \frac{k^2 m_3 m_2 (x_2 - x_3)}{r_{32}^3}$$

$$m_3 \frac{d^2 y_3}{dt^2} = -\frac{k^2 m_3 m_1 (y_1 - y_3)}{r_{31}^3} - \frac{k^2 m_3 m_2 (y_2 - y_3)}{r_{32}^3}$$

$$m_3 \frac{d^2 z_3}{dt^2} = -\frac{k^2 m_3 m_1 (z_1 - z_3)}{r_{31}^3} - \frac{k^2 m_3 m_2 (z_2 - z_3)}{r_{32}^3}$$

In order to solve the problem completely it would be necessary to integrate this simultaneous system of equations. There are nine, each of the second order, so that the problem is said to be of the eighteenth order. Hence when eighteen integrals are found, and the constants determined, the solution is complete.

Six integrals of one type can readily be found, and a discussion of them shows that the center of gravity of the three bodies moves forward in a straight line with uniform velocity. These six integrals give what is known as *the principle of the conservation of the motion of the center of gravity*. Then it is possible to find *three* integrals more of a different type. They furnish the theorem that the sum of the projections upon the *xy*, *yz* and *xz* planes respectively, of the areas described by the radii vectores to the three bodies, each multiplied by the mass of the corresponding body, is constant. The *xy* plane means the plane defined by the *x* and *y* axes, and similarly for the others. When the axes are so chosen on the start that the sum of the projections upon each of two of the planes is zero, the third is the celebrated *invariable plane* discovered by Laplace. These three integrals furnish *the principle of the conservation of areas*. One more integral of a different type still can be obtained, which gives *the principle of the conservation of vis viva*, or the theorem that

the sum of the kinetic and potential energies of the three bodies is constant. This, coupled with the fact that energy is only transformed by friction, leads to the principle of the conservation of energy, which is one of the most far-reaching principles of physical science.

It may be remarked here that integrals precisely similar to these ten hold for a system of any number of bodies, and furnish the same theorems. But at this point in the work difficulties arise, and the problem can in general be solved no further except by methods of approximation. These approximate solutions form the theories of the computation of perturbations, and will require a separate paper for their description. It now remains to mention the special cases which admit of complete solutions.

About one hundred years ago Lagrange wrote a memoir on *the problem of three bodies*, which contained some new and important results. He selected a symmetrical and elegant notation, referring m_2 to m_1, m_3 to m_2 and m_1 to m_3 as origin of coördinates respectively. He derived the integrals corresponding to the ones we have mentioned. That left eight of the original eighteen integrals to be found corresponding to eight unsolved differential equations. He then proved that in this system of eight equations, there were but seven independent ones, and hence but seven new integrals required. Lagrange did not find the physical meaning of this relation between the eight differential equations. It was done however by Jacobi in a beautiful memoir on the same subject, entitled "On the elimination of the nodes in the problem of the three bodies." This appeared in 1844, but was entirely independent of the work of Lagrange. Jacobi took two fictitious bodies having certain defined relations to the three given bodies, and proved that the intersections of their orbit planes were always in the invariable plane; that is, that their lines of nodes in the invariable plane always coincide. He showed how this is equivalent to lowering the problem from one of the eight to one of the seventh order. Astronomers have not been able to solve the problem further unless special assumptions are made.

Lagrange found it impossible to integrate the equations further than that mentioned above without making further limitations. By assuming that the ratios of the distances between the bodies are constants he simplified his equations immensely, and was led to two remarkable special solutions. In one case he found that, if the three bodies were originally placed at the vertices of an equilateral triangle, and started with just the right velocities and directions, they would always form an equilateral

triangle of varying size. And a most remarkable property of their motions would be that each would describe a conic section with reference to either of the others as origin. These relations would be forever preserved, and it would be possible to compute their exact positions at any epoch.

In the other case he found that, if they were originally placed in a straight line, at just the distances apart required by their masses and were started with the proper velocities and directions they would always remain in a straight line, and at the same relative distances from each other. Again the motion of each with reference to either of the others as origin, would be a conic section. About the only advance in this phase of the subject is the recent work of Poincaré, in which he derives certain solutions which he calls "asymptotic," and shows that there are an infinite number of initial conditions of velocity and direction of projection, such that the position of the bodies will be periodic functions of the time.

According to the results of Lagrange, if the Sun, Moon and Earth had been started in a straight line and just right, the Moon might always have been kept opposite the Sun so that we should have full Moon every night in the year. In the fourth volume of his *Mécanique Céleste*, Laplace calculates that, if the Moon had been placed distant from the Earth about one-hundredth of the distance from the Earth to the Sun, in the opposite direction, and started just right, it would always have stayed there, and there would always have been full Moon.

It had been held by theologians that the Moon was a special creation to furnish light by night. Laplace, sharing some of the unnecessary and excessive antagonism to the theologians that was so common among the French at the close of the French revolution, said that if their reasoning were correct the Almighty had failed to obtain the best results possible. In his Système du Monde he says: "Some partisans of final causes have imagined that the Moon has been given to the Earth to light it by night. If this is the case nature has not attained the end that it has proposed, because we are often deprived at the same time of the light of both the Sun and the Moon. In order to have obtained that end it would have sufficed to have placed in the beginning the Moon in opposition with the Sun, in the plane of the ecliptic, at a distance from the Earth equal to a hundredth part of the distance from the Earth to the Sun, and to give to the Moon and to the Earth velocities proportional to their distances from the Sun. Then the Moon, without ceasing to be in opposition with

the Sun, would describe an ellipse around it similar to that of the Earth; these two bodies would succeed each other on the horizon; and, as at this distance the Moon would not be eclipsed, its light would constantly take the place of that of the Sun."

In this case it would be so far away that its apparent surface would be only one-fifteenth as great as it is now; and besides it would be continually in the penumbra of the Earth's shadow. But this system of three bodies would be continually disturbed by the action of the other planets, notably Jupiter. Therefore it becomes a pertinent question whether these slight disturbances, from the exact conditions necessary to maintain the straight-line relation, would be augmented or corrected. In 1845 Liouville investigated the question and found that the slightest disturbance from the conditions necessary for such motion would not only *not* be corrected but would rapidly be increased. So if the Moon had been placed in the particular position indicated by Laplace it would have remained in that relation only a very short time.

It has been pointed out that the problem of three bodies has not been solved completely except in two particular cases. It cannot be doubted that a solution exists for every case, and that it is only waiting for the invention of some new method. The solution of the general case does not seem to be near at hand, and if it is ever accomplished it will be by one possessing thorough preparation and exceptional mathematical ability.

UNIVERSITY OF CHICAGO, Sept. 15, 1897.

LARGE MAGELLANIC CLOUD.

EDWARD C. PICKERING.

Stars whose spectra are of the fifth type consisting mainly of bright lines have hitherto been found only near the central line of the Milky Way. Of the 67 stars of this type so far discovered the average deviation from this line is 2° 39′. For only one object, whose distance is 17° 39′, does the deviation exceed 9°. It is difficult to explain this very close approach to a great circle as these stars fall in a band much narrower than the Milky Way itself. This law of distribution is one of the most important results attained by means of the Henry Draper Memorial. The two Magellanic Clouds closely resemble the Milky Way in appearance, although completely detached from it, and distant from

its central line by about 33° and 45° respectively. From an examination of the photographs of the spectra of the stars in the Large Magellanic Cloud, recently taken with the Bruce Photographic Telescope, Mrs. Fleming has discovered six stars whose spectra are of the fifth type; also that bright hydrogen lines are present in the spectra of seven stars of the first type, and that the spectra of six known nebulæ are gaseous and not continuous. The power of the instrument and the quality of the photographs are shown by the fact that, with one exception, all of these stars are so faint that they have not been included in any of the star catalogues as yet published. A list of these objects is given in the following table. The successive columns contain the approximate right ascensions and declinations for 1900, the galactic longitudes and latitudes of the nebulæ and stars of the fifth type, and a brief description of the objects.

R.A. 1900	Dec. 1900	Gal. Long.	Gal. Lat.	Description.
h m	° ′	°	°	
4 54.6	−69 21	247 14	−35 16	Gaseous nebula. N. G. C. 1743.
4 56.4	−66 37	243 54	−35 44	Type V. Brightest star in N. G. C. 1761.
4 56.5	−66 34	243 51	−35 44	Gaseous nebula. N. G. C. 1763.
5 14.0	−67 34	... ..	.. ..	Type I. *Hβ*, *Hγ* and *Hδ* bright. In N. G. C. 1871.
5 18.9	−69 21	... ..	.. ..	Type I. *Hβ*, *Hγ* and *Hδ* bright. Variable. In N. G. C. 1910.
5 20.1	−69 45	247 10	−33 1	Type V. In N. G. C. 1918.
5 25.6	−68 33	... ..	.. ..	Type I. *Hβ*, *Hγ* and *Hδ* bright. In N. G. C. 1949.
5 30.4	−67 30	244 24	−32 20	Type V.
5 32.0	−71 6	248 37	−31 51	Type V.
5 35.2	−69 49	247 5	−31 43	Type V.
5 35.6	−67 39	244 32	−31 50	Gaseous nebula. N. G. C. 2029.
5 37.2	−69 26	... ..	.. ..	Type I. *Hβ*, *Hγ* and *Hδ* bright. In N. G. C. 2050.
5 39.3	−69 8	246 15	−31 24	Gaseous nebula. N. G. C. 2070. 30 Doradus.
5 39.5	−69 5	246 11	−31 23	Type V.
5 40.6	−69 49	247 2	−31 15	Gaseous nebula. N. G. C. 2079.
5 40.6	−69 42	... ..	.. ..	Type I. *Hβ*, *Hγ* and *Hδ* bright. In N. G. C. 2080.
5 40.6	−69 42	... ..	.. ..	Type I. *Hβ*, *Hγ* and *Hδ* bright. In N. G. C. 2080.
5 40.7	−69 27	246 37	−31 16	Gaseous nebula. In N. G. C. 2081.
5 41.0	−69 26	... ..	.. ..	Type I. *Hβ*, *Hγ* and *Hδ* bright. In N. G. C. 2081.

The fifth star is variable and has a range of rather more than one magnitude. It is identical with Gilliss No. 3092.

The tenth object is identical with the second object, announced as a gaseous nebula, in Circular No. 17. Small gaseous nebulæ and faint fifth type stars can be distinguished photographically only by the wave length of the principal line in their spectra. Accordingly, on the Bache plates the bright line was assumed to be due to a gaseous nebula and was identified with a faint ad-

jacent star. Two Bruce plates show that the spectrum is that of a fifth type star following $0^m.1$, north 3′.

The gaseous character of the nebulosity surrounding 30 Doradus is well known. These photographs show that several objects closely adjacent to it have bright lines in their spectra.

After the above description had been prepared a letter was received from Peru, from which it appeared that the presence of bright lines in the spectra of several of these stars had already been found by Dr. Stewart at Arequipa. His description of each object is given below preceded by its right ascensson:

R. A. $4^h\ 54^m.6$. Four bright lines including $H\beta$, $H\gamma$ and $H\delta$.

R. A. $5^h\ 14^m.0$. $H\beta$ and $H\gamma$ bright.

R. A. $5^h\ 18^m.9$. $H\beta$, $H\gamma$ and $H\delta$ bright.

R. A. $5^h\ 20^m.1$. $H\beta$ bright and broad.

R. A. $5^h\ 25^m.6$. $H\beta$ somewhat bright, not intense.

R. A. $5^h\ 32^m.0$. $H\beta$ somewhat bright, broad, not intense.

R. A. $5^h\ 35^m.2$. $H\beta$ bright and broad, partial spectrum only visible.

R. A. $5^h\ 37^m.2$. $H\beta$, $H\gamma$ and $H\delta$ bright.

R. A. $5^h\ 39^m.3$. $H\beta$ and $H\delta$ bright.

R. A. $5^h\ 40^m.6$ (first). $H\beta$ bright and broad.

R. A. $5^h\ 40^m.6$ (second or third). $H\beta$, $H\gamma$ and $H\delta$ bright and broad.

R. A. $5^h\ 41^m.0$. $H\beta$, $H\gamma$ and $H\delta$ bright and sharp.

The line called $H\beta$ by Dr. Stewart in the first, ninth and tenth of these objects is probably the line 5007, characteristic of gaseous nebulæ. The line called $H\beta$ in the fourth, sixth and seventh objects is probably the line 4688, characteristic of spectra of the fifth type.

HARVARD COLLEGE OBSERVATORY, Circular No. 19.
September 28, 1897.

LIFE SKETCH OF "OLD STARS," AMERICAN ASTRONOMER AND GENERAL.

ORRIN E. HARMON.

FOR POPULAR ASTRONOMY.

One beautiful evening in the spring of 1812, a little boy, with his two older brothers, stood in the front yard of their home in the wilds of Kentucky. The Moon shone in a clear sky; and as the little boy looked out from the deep forests into the starlit heavens, the scene deeply impressed him. Suddenly he turned to his brothers and said, "Mans can't make moons!"

This was his first lecture on astronomy, and a remarkable lecture it was for a boy but three years old. The name of this boy was Ormsby Macknight Mitchel; and his childish exclamation about the Moon seemed prophetic of his future career as a great teacher of astronomy.

Ormsby Macknight Mitchel was born in Union County, Kentucky, July 28, 1809. You will at once associate the year and state with the birth of Abraham Lincoln. But Lincoln was born in Hardin County, little more than one hundred miles east of Union County where Mitchel was born.

Ormsby's father was a well educated man for that day, and he was fond of mathematics and astronomy.

He had moved from Virginia to Kentucky in 1804. But the father died soon after the settlement in Kentucky. In this forest solitude all the family, except a daughter, lived till 1816, when they removed to Lebanon, Ohio, whither the daughter had preceded them soon after her marriage.

The journey to Lebanon was made through a wilderness, and Ormsby rode horseback behind his brother. The family reached Covington opposite Cincinnati. They crossed the Ohio river in a violent storm which seriously interfered with the voyage. But they braved the storm and made a safe landing.

Ormsby little thought, as he stepped on the north bank of the river at Cincinnati, that a large city would grow up there, and that one day he would be the founder and director of a great astronomical Observatory overlooking the city.

At Lebanon, Ormsby received his boyhood education. He was a good student and was ambitious to excel. He liked school contests, and it is said that when a neighboring school was once contesting with his own, all the pupils of his school were "turned down" except himself.

He stood the contest until he dropped from sheer exhaustion. "Boys," he said, "you may kill me, but you shall never drive me off this field."

Another incident shows his deep interest in his studies.

"He had been interested in a problem in arithmetic. Suddenly the scholars were startled by seeing him strike his head, and exclaim unconscious of the rule and silence he was breaking, 'Old head, I knew you could do it'."

Ormsby desired to go to West Point where he could get a scientific military education. He obtained an appointment, and with swelling hopes, he started for the National Military Academy. He went on horseback to Sandusky, a distance of one hundred

and forty miles, through the lonely forests, with no road except a blazed trail. From Sandusky he went to Buffalo on the lake, and then on a canal boat to Albany.

He now sailed down the Hudson to West Point. This seems like a round about way to reach West Point from a place near Cincinnati; but it was probably the best route in young Mitchel's day.

Arrived at West Point, he was entered as a cadet, his age then being fifteen years and eleven months.

Young Mitchel did not like the fare served to the cadets. This is what he says about it in a letter to his mother:

"The first meal I ate as a cadet was on Wednesday. We had soup for dinner. I took one mouthful and that satisfied me. I saw some who were eating molasses (and you know I was extremely fond of our molasses), so I called for the pitcher of molasses, thinking what a fine dinner I would make on bread and molasses, but the first taste was sufficient. 'Twas the most filthy kind of Orleans molasses. There was some black-looking stuff, contained in a tin pan, which was honored with the name of pudding; but I had already received my dose, so I thought it not expedient to risk any further by tasting the pudding. I munched away on a crust of bread until the word 'rise' was given, got up, and as the saying is, 'retired in disgust.'"

But he managed to survive his "disgust," and altogether he had a pleasant time as a cadet, graduating in 1829. The class of '29 at West Point became as famous as the class of '29 at Harvard College.

At the latter place the class of '29 numbered among others, Benjamin Peirce, the celebrated astronomer, Oliver Wendell Holmes, the genial poet, and the late Samuel F. Smith, author of "America." Among the classmates of Mitchel at West Point were Robert E. Lee and Joseph E. Johnston, both of whom were afterwards noted Confederate generals.

Upon his graduation, Mitchel became assistant professor of mathematics at the Military Academy. This gave him time for study, and it also proved to be the romantic period of his life. He could play the guitar skillfully, and we can well imagine what heavenly dreams came to him as he mixed the notes of the guitar with the lulling murmurs of the Hudson. And now his dreams and music turned to her who was to become his life partner. Her name was Louisa Trask. She and Mitchel were married in 1831.

Mitchel gave up his duties as assistant professor to go on military duty in Florida. He served but a short time, resigned his

commission, and moved to Cincinnati. Here he was admitted to the bar, but he never seriously engaged in the law practice. His scientific turn of mind better fitted him for a teacher than for a lawyer.

In 1836 he was elected professor of mathematics and engineering in the Cincinnati College. It was in 1841, while serving as professor in this College, that he formed the idea of a great Observatory at Cincinnati. It was a huge undertaking, and was beset with trials and difficulties. But his energy and perseverance overcame them all, for he still acted on the principle that nerved him in his school contest "Boys, you may kill me, but you shall never drive me off this field." It would be interesting to give in detail the chain of events that led to the founding and equipment of this Observatory, the first watch tower of the skies erected in the United States. But this sketch commands me to be brief. It may be stated, however, that Mitchel visited Europe, met Airy, Herschel, Arago and other European astronomers.

He also visited the manufacturers of telescopes, and succeeded in obtaining one which was then the largest in the United States, and with the exception of the equatorial at Pulkowa, the finest refracting telescope in the world.

The Observatory was finished in 1845, and Mitchel was its Director. He held this post till 1860, when he became Director of the Dudley Observatory at Albany, New York.

During this period of fifteen years, he lectured and wrote on astronomy, beside taking the general management of the Observatory. His lectures were delivered to large audiences in Cincinnati, New York, Brooklyn, Boston and other leading cities. He had the rare gift of making astronomy attractive to the public. His lectures and writings show thorough knowledge, clear illustration and poetical expression. Among his books may be mentioned, "Planetary and Stellar Worlds," one of the grandest contributions ever made to astronomical literature.

While Mitchel was Director of the Dudley Observatory, the Civil War broke out. His loyalty to his country was as fervent as was his devotion to the stars.

He entered the army in defense of the Union, was a brave soldier, and rose to the rank of major general.

While at Port Royal, South Carolina, he was stricken with yellow fever, of which he died in November, 1862. His career as a general, though brief, was glorious. He stood high in the confidence of President Lincoln, and of all others who knew him.

It was during his war service that he received the name "Old

Stars." This title was given to him by the soldiers as soon as they learned he was an astronomer. An amusing incident shows how his soldiers regarded him, as an astronomer as well as a general:

"In camp at Bacon Creek, Ky., on a very dark and stormy winter night, the guard was placed as usual, but along about three o'clock had grown careless—more anxious to find shelter than to note everything that was stirring. Suddenly those of us who were 'off duty' received a startling surprise. The men on watch had permitted somebody to come up to our post unchallenged, and we knew nothing of it until this person was in our midst, seizing the soldiers in no gentle manner by arm and collar, and shaking them or tumbling them out of the guard tent, as he exclaimed, 'Why don't you turn out the guard?' Some of the soldiers were for resisting; but all were submissive enough when the word passed around, 'It's old Mitchel himself.'

We were very soon in our places, and then we listened to a lecture, as we stood in the rain, *not* on the subject of astronomy! When the general was gone, the soldiers grumbled, and wished they had an officer 'who had not studied the stars so long, that he could not sleep at night himself and would not let anybody else sleep!' But we resolved not to be caught in the same way again; and we never were!

We now knew, in our division, that the only way to get along in peace with our commander was to faithfully perform every part of military duty.

We exercised the soldier's prerogative in grumbling, but we loved and trusted him for all that, and would have followed him to Mobile or Savannah without hesitation, assured that he would have carried safely through what he undertook."

LIBERAL, Barton Co., Missouri.

OCCULTATIONS.

J. MORRISON, M. A., M. D., PH. D.

FOR POPULAR ASTRONOMY.

An occultation of a fixed star is a total eclipse of it by the Moon, and is computed in the same manner as an eclipse of the Sun, but owing to the fact that the star has neither parallax nor semi-diameter the formulæ become considerably simplified. The shadow is a cylinder with a constant radius equal to k which is therefore to

be substituted for $L = l - i\zeta$ in Eq. (66); the coördinates of the point Z become the R. A. and Decl. of the star and z and ζ are not in general required.

Let α' and δ' denote the R. A. and Decl. of the star, then by (57) we have, r being equal to $\frac{1}{\sin \pi}$,

$$x = \frac{\cos \delta \sin (\alpha - \alpha')}{\sin \pi}$$
$$y = \frac{\sin \delta \cos \delta' - \cos \delta \sin \delta' \cos (\alpha - \alpha')}{\sin \pi} \qquad (159)$$

and at the moment of geocentric conjunction $\alpha = \alpha'$, the above become

$$x = 0$$

and

$$Y = \frac{\sin (\delta - \delta')}{\sin \pi} \qquad (160)$$

For the coördinates of the place of observation we shall have from Eq. (60)

$$\xi = \rho \cos \varphi' \sin (\mu - \alpha')$$
$$\eta = \rho \left(\sin \varphi' \cos \delta' - \cos \varphi' \sin \delta' \cos (\mu - \alpha') \right) \qquad (161)$$

where μ is the sidereal time and therefore $\mu - \alpha'$ is the star's hour angle. The fundamental equation (67) becomes

$$(x - \xi)^2 + (y - \eta)^2 = k^2 \qquad (162)$$

which of course can be expressed in the form

$$k \sin Q = x - \xi$$
$$k \cos Q = y - \eta$$

To obtain the variations in a unit of time, of x, y, ξ and η, at the time of conjunction we have only to differentiate Eqs. (159) and (161) and put $\alpha = \alpha'$, $\sin \pi$ being regarded as constant; thus we have

$$\frac{dx}{dT} \text{ or } x' = \frac{1}{\sin \pi} \left(\cos \delta \frac{d\alpha}{dT} \sin 1'' \right)$$
$$\frac{dy}{dT} \text{ or } y' = \frac{1}{\sin \pi} \left(\cos (\delta - \delta') \frac{d\delta}{dT} \sin 1'' \right) \qquad (163)$$

and

$$\frac{d\xi}{dT} \text{ or } \xi' = \rho \cos \varphi' \cos (\mu - \alpha') \frac{d\mu}{dT} \sin 1''$$
$$\frac{d\eta}{dT} \text{ or } \eta' = \rho \cos \varphi' \sin \delta' \sin (\mu - \alpha') \frac{d\mu}{dT} \sin 1'' \qquad (164)$$
$$= \xi \sin \delta' \frac{d\mu}{dT} \sin 1''$$

If one hour be taken as the unit of time

$$\frac{d\mu}{dT}\sin 1'' = 54147''.84 \sin 1'' = \mu'$$

and $$\log \mu' = 9.419156$$

and if one minute be the unit, then

$$\log \mu' = 7.641005$$

For any time τ we shall have

$$\begin{aligned} x &= x'\tau \\ y &= Y + y'\tau \end{aligned} \qquad (165)$$

THE ELEMENTS OF OCCULTATIONS.

To facilitate the computation of occultations at any given place certain quantities called elements are given in the American Ephemeris which we now proceed to explain.

In the columns refering to the star, those headed $\Delta\alpha$ and $\Delta\delta$ are the corrections in R. A. and Decl., to be applied to the mean R. A. and Decl. at the beginning of the year to obtain the apparent position at the date of the occultation. The computation of these quantities which are the results of precession, nutation and aberration, has been explained in a former paper. The Washington mean time of conjunction is equal to the Greenwich time of conjunction minus the longitude of Washington. On pages V to XII inclusive of each month is given the R. A. of the Moon for every hour of Greenwich time and a mere inspection will show the hours between which geocentric conjunction will take place. For some two or three hours before and after conjunction subtract the Moon's R. A. from the star's and let the results which we denote by f, be arranged as follows, and let Δ_1, Δ_2 and Δ_3 be the1st, 2d, &c., differences:

DATE.	f	Δ_1	Δ_2	Δ_3
T_{-2}	a_{+2}			
		b		
T_{-1}	a_{+1}		c	
		b_1		d
T_0	a_0		c_1	
		b_2		d_1
T_1	a_{-1}		c_2	
		b_3		
T_2	a_{-2}			

be substituted for $L = l - i\zeta$ in Eq. (66); the coördinates of the point Z become the R. A. and Decl. of the star and z and ζ are not in general required.

Let α' and δ' denote the R. A. and Decl. of the star, then by (57) we have, r being equal to $\frac{1}{\sin \pi}$,

$$x = \frac{\cos \delta \sin (\alpha - \alpha')}{\sin \pi}$$
$$y = \frac{\sin \delta \cos \delta' - \cos \delta \sin \delta' \cos (\alpha - \alpha')}{\sin \pi} \quad (159)$$

and at the moment of geocentric conjunction $\alpha = \alpha'$, the above become

$$x = 0$$

and

$$Y = \frac{\sin (\delta - \delta')}{\sin \pi} \quad (160)$$

For the coördinates of the place of observation we shall have from Eq. (60)

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$$\eta = \rho (\sin \varphi' \cos \delta' - \cos \varphi' \sin \delta' \cos (\mu - \alpha')) \quad (161)$$

where μ is the sidereal time and therefore $\mu - \alpha'$ is the star's hour angle. The fundamental equation (67) becomes

$$(x - \xi)^2 + (y - \eta)^2 = k^2 \quad (162)$$

which of course can be expressed in the form

$$k \sin Q = x - \xi$$
$$k \cos Q = y - \eta$$

To obtain the variations in a unit of time, of x, y, ξ and η, at the time of conjunction we have only to differentiate Eqs. (159) and (161) and put $\alpha = \alpha'$, $\sin \pi$ being regarded as constant; thus we have

$$\frac{dx}{dT} \text{ or } x' = \frac{1}{\sin \pi} \left(\cos \delta \frac{d\alpha}{dT} \sin 1'' \right)$$
$$\frac{dy}{dT} \text{ or } y' = \frac{1}{\sin \pi} \left(\cos (\delta - \delta') \frac{d\delta}{dT} \sin 1'' \right) \quad (163)$$

and

$$\frac{d\xi}{dT} \text{ or } \xi' = \rho \cos \varphi' \cos (\mu - \alpha') \frac{d\mu}{dT} \sin 1''$$
$$\frac{d\eta}{dT} \text{ or } \eta' = \rho \cos \varphi' \sin \delta' \sin (\mu - \alpha') \frac{d\mu}{dT} \sin 1'' \quad (164)$$
$$= \xi \sin \delta' \frac{d\mu}{dT} \sin 1''$$

If one hour be taken as the unit of time

$$\frac{d\mu}{dT}\sin 1'' = 54147''.84 \sin 1'' = \mu'$$

and $$\log \mu' = 9.419156$$

and if one minute be the unit, then

$$\log \mu' = 7.641005$$

For any time τ we shall have

$$\begin{aligned} x &= x'\tau \\ y &= Y + y'\tau \end{aligned} \qquad (165)$$

THE ELEMENTS OF OCCULTATIONS.

To facilitate the computation of occultations at any given place certain quantities called elements are given in the American Ephemeris which we now proceed to explain.

In the columns refering to the star, those headed $\Delta\alpha$ and $\Delta\delta$ are the corrections in R. A. and Decl., to be applied to the mean R. A. and Decl. at the beginning of the year to obtain the apparent position at the date of the occultation. The computation of these quantities which are the results of precession, nutation and aberration, has been explained in a former paper. The Washington mean time of conjunction is equal to the Greenwich time of conjunction minus the longitude of Washington. On pages V to XII inclusive of each month is given the R. A. of the Moon for every hour of Greenwich time and a mere inspection will show the hours between which geocentric conjunction will take place. For some two or three hours before and after conjunction subtract the Moon's R. A. from the star's and let the results which we denote by f, be arranged as follows, and let Δ_1, Δ_2 and Δ_3 be the1st, 2d, &c., differences:

DATE.	f	Δ_1	Δ_2	Δ_3
T_{-2}	a_{-2}			
		b		
T_{-1}	a_{+1}		c	
		b_1		d
T_0	a_0		c_1	
		b_2		d_1
T_1	a_{-1}		c_2	
		b_3		
T_2	a_{-2}			

Now we have to find when this variable function becomes zero. If conjunction takes place between the dates T_{-1} and T_0 for instance and $a^{(t)}$ be the value of the function at the date t, we shall have by the ordinary formulæ of interpolation

$$a^{(t)} = a_1 + tb_1 + \frac{t\,(t-1)}{2}\,c_0 + \text{etc.} = 0 \qquad (166)$$

where $c_0 = \frac{1}{2}\,(c + c_1)$, and solving for t, neglecting the square, we get

$$t = \frac{2a_1}{c_0 - 2b_1}$$

Therefore the date of conjunction is $T_{-1} + t$ and as a check the Moon's R. A. computed for this state must be equal to α', and if not, a simple interpolation will be necessary to make them so. For the Washington mean time of conjunction thus found, we find the sidereal time μ, then the hour angle $H = \mu - \alpha'$, positive when west, negative when east.

The quantities Y, x' and y' are found from equations (160) and (163). The limiting parallels in the last two columns will be explained hereafter.

We are now prepared to explain the computation of an occultation for any place where it is visible.

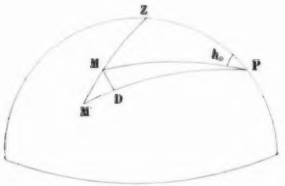
If λ be the west longitude of the place we shall have for the local hour angle

$$h_0 = H - \lambda.$$

The next step is to find the time of *apparent* conjunction, which will be near the middle of the occultation; we can then assume two dates equally distant from the time of apparent conjunction, for the approximate times of immersion and emersion. By reason of the Moon's parallax in R. A. the time of apparent conjunction will be accelerated or retarded according as the hour angle is east or west of the meridian, and the amount of this acceleration or retardation is found by dividing the parallax in R. A. by the Moon's variation (per minute or hour) in R. A. as given on pages V to XII of each month.

In the diagram let P be the north pole, Z the zenith of the place, M the Moon's true place and M' its apparent place when in apparent conjunction with the star; then MPM' is the parallax in R. A. which we denote by Π; ZPM is the Moon's true local hour angle h_0 just found, MM' the parallax in altitude, $ZP = 90 - \varphi'$ and $PM = 90^\circ - \delta$.

Draw the arc MD perpendicular to PM', then we shall have



$$\sin \Pi = \frac{\sin MD}{\sin PM}$$

$$= \frac{\sin MM' \sin ZM'P}{\sin PM}$$

$$= \frac{\sin \pi \sin ZM' \sin ZM'P}{\sin PM}$$

$$= \frac{\sin \pi \sin ZP \sin ZPM'}{\sin PM}$$

$$= \frac{\sin \pi \cos \varphi' \sin (h_0 + \Pi)}{\cos \delta} \quad (167)$$

But since Π is always small and we require only an approximate value, it will be practically sufficient to use

$$\sin \Pi = \frac{\sin \pi \cos \varphi' \sin h_0}{\cos \delta}$$

or expressing Π in seconds of arc

$$\Pi'' = \frac{\sin \pi \cos \varphi' \sin h_0}{\cos \delta \sin 1''} \quad (168)$$

Now if we denote by $\frac{d\alpha}{dT}$ the Moon's variation in R. A. in one minute of mean time as given in the ephemeris and by τ the acceleration or retardation in minutes we shall evidently have

$$\tau = \frac{\Pi}{\frac{d\alpha}{dT}} = \frac{\sin \pi \cos \varphi' \sin h_0}{\cos \delta \frac{d\alpha}{dT} \sin 1''}$$

$$= \frac{\cos \varphi' \sin h_0}{x'} \quad \text{by (163)} \quad (169)$$

The sign of τ will be the same as that of h_0, since cos φ' and x' are always positive.

If T be the time of geocentric conjunction then the date of apparent conjunction will be $T + \tau$ and the apparent hour angle at the place $h_0 + \tau$.

Eq. (169) furnishes the means of computing Downes's Table which gives the values of τ with x' and h_0 as arguments, and for every 6° of latitude from 0° to 72°. It is a Table of double entry, the extreme and mean values of x' at the top, and h_0 at the left hand side of the page.

For intermediate values of the Lat, and of x' and h_0 a troublesome interpolation will be required, but it will be far more convenient to compute τ directly from (169).

Assuming the average duration of an occultation to be one hour, if we subtract and add $0^h.5$ to $T + \tau$ we shall have approximate dates for the computation of immersion and emersion.

Accordingly if we put $\tau_1 = \tau - 0^h.5$
and $\tau_2 = \tau + 0\ .5$

the approximate time of immersion $= T + \tau_1$
" " emersion $= T + \tau_2$

and, the corresponding hour angles $h_0 + \tau_1$ and $h_0 + \tau_2$ which of course must be expressed in arc.

Therefore Eqs. (161), (164) and (165) now become

$$\begin{aligned}
\xi &= \rho \cos \varphi' \sin (h_0 + \tau_0) \\
\eta &= \rho (\sin \varphi' \cos \delta' - \cos \varphi' \sin \delta \cos (h_0 + \tau_0)) \\
\xi' &= [9.419156]\, \rho \cos \varphi' \cos (h_0 + \tau_0) \\
\eta' &= [9.419156]\, \xi \sin \delta' \\
x &= x' \tau_0 \\
y &= Y + y' \tau_0 \text{ where } \tau_0 \text{ stands for } \tau_1 \text{ or } \tau_2
\end{aligned} \qquad (170)$$

Having computed x, y, x', y', ξ, η, ξ' and η' for the approximate dates $T + \tau_1$ and $T + \tau_2$ put as in the case of eclipses

$$m \sin M = x - \xi \qquad n \sin N = x' - \xi'$$
$$m \cos M = y - \eta \qquad n \cos N = y' - \eta'$$

then we shall have

$$\sin \psi = \frac{m \sin (M - N)}{k}, \qquad k = 0.27227$$

and
$$\tau = \frac{k \cos \psi}{n} - \frac{m \cos (M - N)}{n} \qquad (171)$$

and
$$T_1 = T \pm \tau$$

in which $\cos \psi$ is negative for immersion and positive for emersion.

For a second approximation, recompute for the dates just found which will frequently be considerably in error especially if the duration of the occultation be only a few minutes.

In solar eclipses the position angle was referred to the Sun's centre but in occultations it must be referred to the Moon's, and will therefore be equal to $Q + 180°$, that is

$$P = N - \psi \text{ for immersion}$$
$$P = N + \psi + 180° \text{ for emersion.}$$

If in any case $\sin \psi > 1$, the star can not be occulted at the given place.

Limiting Parallels.

At any time $T_1 = T_0 + \tau_0$, the least distance from a point on the limiting curve to the axis of the cylinder is $k = 0.27227$, the Earth's

radius being unity. Then as in the case of eclipses we shall have for this date the equations

$$\begin{aligned} k \sin Q &= x - \xi + (x' - \xi')\tau_0 \\ k \cos Q &= y - \eta + (y' - \eta')\tau_0 \end{aligned} \qquad (172)$$

and putting

$$\begin{aligned} m \sin M &= x - \xi & n \sin N &= x' - \xi' \\ m \cos M &= y - \eta & n \cos N &= y' - \eta' \end{aligned} \qquad (173)$$

the above become after reduction

$$\begin{aligned} k \sin (Q - N) &= m \sin (M - N) \\ k \cos (Q - N) &= m \cos (M - N) + n\tau_0 \end{aligned}$$

the sum of whose squares, is

$$k^2 = m^2 \sin^2 (M - N) + [m \cos (M - N) + n\tau_0]^2$$

which will be a minimum when the last term is zero or when

$$\tau_0 = - \frac{m \cos (M - N)}{n}$$

and therefore $$k = \pm m \sin (M - N)$$

Expanding this equation and restoring the values of $m \sin M = x - \xi$ and $m \cos M = y - \eta$, and also neglecting the changes of ξ and η for the present purpose, that is, taking $n \sin N = x'$ and $n \cos N = y'$, we obtain

$$(x - \xi) \cos N - (y - \eta) \sin N = \pm k \qquad (174)$$

Now if x_0 and y_0 be the values of x and y for the assumed epoch T_0 which may be the time of geocentric conjunction, we shall have for any other time $T_1 = T_0 + \tau_0$, the following values of x and y, viz:

$$x = x_0 + n \sin N \,.\, \tau_0 \quad \text{and} \quad y = y_0 + n \cos N \,.\, \tau_0$$

and the Eq. (174) becomes for this epoch

$$(x_0 - \xi) \cos N - (y_0 - \eta) \sin N = \pm k \qquad (175)$$

Taking the Earth as a sphere, the last of Eq. (79) is

$$\sin \varphi = \eta \cos \delta' + \zeta \sin \delta' \qquad (176)$$

and the last of Eq. (78) is

$$\xi^2 + \eta^2 + \zeta^2 = 1 \qquad (177)$$

The problem is now reduced to finding the maximum and minimum values of φ which fulfill the conditions expressed by these last three equations.

The solution is obtained by the following peculiar and elegant transformation due to Bessel.

Expanding (175) we have after transposing

$$-\xi \cos N + \eta \sin N = -x_0 \cos N + y_0 \sin N \pm k$$

Put $a = -\xi \cos N + \eta \sin N$

and take $b = \xi \sin N + \eta \cos N$ so that $\xi^2 + \eta^2 = a^2 + b^2$

and solving for ξ and η we have

$$\xi = -a \cos N + b \sin N$$
$$\eta = a \sin N + b \cos N$$

and (177) becomes $1 = a^2 + b^2 + \zeta^2$ (178)

where $a = -x_0 \cos N + y_0 \sin N \pm k$, a *constant* quantity, since we may assume x' and y' to be constant, $\tan N = \frac{x'}{y'}$ and N to be taken less than 90° and positive.

The last of (178) can be put in the following form by assuming A and χ so as to satisfy the equations

$$\begin{aligned} \cos A &= a \\ \sin A \cos \chi &= b \\ \sin A \sin \chi &= \zeta \end{aligned} \qquad (179)$$

where sin A is restricted to positive values.

Substituting in the second of (178) we get

$$\eta = \cos A \sin N + \sin A \cos \chi \cos N$$

and substituting these values of η and ζ in (176) we have

$$\sin \varphi = \cos A \sin N \cos \delta' + \sin A \cos \chi \cos N \cos \delta' + \sin A \sin \chi \sin \delta' \qquad (180)$$

Again assume

$$\begin{aligned} \sin B &= \sin N \cos \delta' \\ \cos B \cos \theta &= \cos N \cos \delta' \\ \cos B \sin \theta &= \sin \delta' \end{aligned} \qquad (181)$$

then, $$\sin \varphi = \cos A \sin B + \sin A \cos B \cos (\theta - \chi) \qquad (182)$$

in which the only variables are φ and χ, for A, B and θ are known from (179) and (181).

Since cos A sin B is positive, sin φ is a maximum

when $\cos (\theta - \chi) = 1$ or when $\theta - \chi = 0$

and a minimum when $\cos (\theta - \chi) = -1$ or when $\theta - \chi = 180°$.

Therefore for the limits we have $\sin \varphi = \sin (B \pm A)$

that is, for the northern limit $\varphi = B + A$

southern " $\varphi = B - A$

Since ζ is always positive sin χ is positive, and when $\theta = \chi$, sin θ must also be positive when sin δ' is positive. Therefore the formula

$$\varphi = B + A$$

gives the northern limit of visibility only when the star has north

declination and for similar reasons, $\varphi = B - A$ gives the southern limit only when the star has south declination.

The other limit in each case must evidently be one of the points in which the northern or southern limiting curve intersects the rising and setting limits or when $\zeta = 0$ which according to (179) gives $\sin \chi = 0$ and $\cos \chi = \pm 1$ and these substituted in (180) give

$$\sin \varphi = \sin (N \pm A) \cos \delta'$$

The upper sign gives the northern limit when $\varphi = B - A$ gives the southern and the lower sign gives the southern limit when $\varphi = B + A$ gives the northern.

Now the epoch T_0 for which x_0 and y_0 are taken, is arbitrary and may be the time of geocentric conjunction, when $x_0 = 0$ and $y_0 = Y$, given in the ephemeris, then we shall have

$$\begin{aligned} &\cos A_1 = a && A < 180^\circ \\ &\quad = Y \sin N \pm k \\ \text{and} \quad &\sin B = \sin N \cos \delta' && B < 90^\circ \\ &\varphi_1 = B \pm A_1 && \qquad (183) \\ &\cos A_2 = Y \sin N \mp k \\ &\sin \varphi_2 = \sin (N \mp A_2) \cos \delta' && N < 90^\circ \end{aligned}$$

Use the upper sign when Decl. of star is north, φ_1 will then be the northern and φ_2 the southern limit.

Use the lower sign when Decl. of star is south, φ_1 will then be the southern and φ_2 the northern limit.

If the shadow extends beyond the Earth, $\cos A_1$ and $\cos A_2$ will have imaginary values; in the former case the occultation is visible beyond the elevated pole and therefore the extreme limits will be $\varphi_1 = +90^\circ$ or -90° according to the sign of δ', and in the latter the value of φ_2 will be the latitude of the point nearest the depressed pole and then $\varphi_2 = \delta' - 90^\circ$ or $\varphi_2 = \delta' + 90^\circ$ according as δ' is positive or negative.

It sometimes happens that the numerical value of $\varphi_1 = B \pm A_1$ in (183) exceeds 90°, in which case $\varphi_1 = 180^\circ - (B \pm A_1)$ or $\varphi_1 = -180^\circ - (B \pm A_1)$, these having the same sign.

Since the limiting curves cannot coincide with the parallels of latitude but intersect the meridians at various angles, an occultation is not visible at all places between the extreme latitudes. In most cases a special computation will be necessary to determine whether or not the occultation will be visible at any given place, and especially is this so when the place is near the limiting curves which are only approximations at best and may be in error a degree or even more.

In the occultations of planets, we proceed in the same manner, using the relative parallax and taking the semi-diameter of the planet into account as in the case of eclipses but the shadow may still be regarded as a cylinder of constant radius.

LIST NO. 3 OF NEBULÆ DISCOVERED AT THE LOWE OBSERVATORY FOR 1900.0

LEWIS SWIFT.

For Popular Astronomy.

List No. 1 of 50 nebulæ discovered here was published in *Gould's Astronomical Journal* of Nov. 13, 1896. List No. 2 of 25 was recently published in *Monthly Notices* and in *Publications of the Astronomical Society of the Pacific*. This one as will be seen consists wholly of southern nebulæ. It is a field rich in nebulæ which that "mighty Nimrod" Sir Wm. Herschel who hunted the sky over could not reach. Several are quite bright and a few are interesting.

I have examined Gale's ring nebula, R. A. $21^h\,53^m\,10^s$ Decl. $-39°\,53'\,42''$ and find it an interesting one, increasing the number now known to seven. It bears considerable resemblance to the one between Beta and Gamma Lyræ, but is not as bright, nor will it bear magnifying like that celebrated one, though it is too far south for me to do justice to it. It is remarkable that it escaped detection so long. Numbers 1 and 6 are singular specimens of nebulæ, perhaps deserving of a new classification. I have lately seen three, all looking exactly alike. N. G. C. 1288 is considerably elongated in meridian. It is not round as Sir J. Herschel says. N. G. C. 1340 must be struck out, it is identical with 1344 as has been suspected. I examined the locality thoroughly for 1340 and I am certain that it does not exist. Sometime I intend to take up this matter of doubtful nebulæ. I am glad I have at length found in Barnard's field a nebula his keen eye failed to see. See No. 24.

No.	Date.	Right Ascension h m s	Declination. ° ′ ″	Description.
1	Aug. 10	0 46 45	−35 0 43	*pB. eeS. E.* with 200 looks like a nebulous *D* Uranus.
2	Sept. 4	0 55 0	−40 53 51	*vE. vS. R.*
3	" 4	1 9 45	−33 11 33	*eeF. S. eeE* a ray no * star near.
4	" 4	1 23 35	−36 17 3	*eeF. pS. R. v dif.*
5	" 4	1 33 10	−34 29 45	*vF. S. R. eF* * near *nf.*
6	" 6	1 46 45	−30 26 20	*pB. eS. lE.* like a *D* nebulous no * near with 132 and 200. See No. 1.

No.	Date.	Right Ascension h m s	Declination. ° ′ ″	Description.
7	" 6	1 53 45	−33 46 44	*eeeF. pS. R.* 7*m** in field *nf.* Another suspected.
8	" 4	2 6 0	−23 29 40	*vF. S. vE.* one * *nr.*
9	" 5	2 11 0	−31 41 30	*pB. pS. lE.*
10	" 6	2 34 3	−27 52 25	*pB. cS. R.* 8*m* * pretty close *p.*
11	" 5	2 44 30	−31 42 30	*vF. pS. R.* 1st of 3.
12	" 5	2 44 32	−31 36 32	*pF. pS. R.* 2d of 3.
13	" 5	2 45 4	−31 36 32	*pF. pS. lE.* 3d of 3.
14	July 22	20 19 10	−31 11 37	*eF. pS. lE.* wide *D* * near *s.*
15	" 25	20 20 50	−36 20 57	*pB. vS. eE.*
16	Aug. 29	20 22 0	−36 22 19	*eeS. eE.* in meridian.
17	" 29	20 24 30	−33 50 57	*pF. pS. lE.*
18	" 29	20 36 50	−30 11 30	*vF. pS. R.* 2*F st nr nf* point to it. 1st of 3.
19	" 29	20 37 5	−30 11 30	*eeF. cS. eE.* 2d of 2. *edif. nr* the *p* * of several in segment of a circle.
20	" 29	20 37 30	−30 1 30	*eeeF. pS. vE. eeedif.* 3d of 3.
21	July 9	21 26 5	−37 9 9	*eF. pS. R.* an *e* wide *D** of 30*s.*
22	Aug. 31	22 3 5	−28 21 11	*eeF. vS. vE.* right angled triangle with 2*F st. nr sf.*
23	" 8	22 36 0	−45 19 15	*pF. pL. R. F***nr sf.*
24	Sept. 4	22 51 10	−37 7 5	*eeeF. v S.ueE.* a ray almost a line. *np* of 1459 Index Cat.
25	" 4	22 52 20	−36 35 2	*vF. vS. R. S. f* of 2.
26	" 4	22 52 30	−36 24 0	*pB. pS. R. np* of 2.
27	Aug. 8	23 13 50	−42 49 45	*eeF. S. cE. f* of 3, *f* 7599.
28	" 8	23 16 15	−43 3 20	*eeeF. pL. R.* 10 *m** *nr sp.* 11 *m*f. eeedif.*
29	" 8	23 23 8	−42 2 0	*pB. pS. R.* 9*m** close *s.*
30	" 8	23 26 59	−45 36 18	*vF. vS. R. bet* 2 *st.* 8 *m** *sp.*

LOWE OBSERVATORY, Echo Mountain,
Sept. 12, '97.

LIST NO. 4 FOR 1900.0 OF NEBULÆ DISCOVERED AT THE LOWE OBSERVATORY, ECHO MOUNTAIN, CALIFORNIA.

LEWIS SWIFT.

FOR POPULAR ASTRONOMY.

No.	Date.	R. A. h m s	Decl. ° ′ ″	
1	Sept. 23 1897	0 11 0	−39 52 20	*eeeF. vL. eE.* close *f* 55. See note.
2	Oct. 3 "	0 54 30	−34 51 32	*pB. vS. R.* 2 *st nf.* and 2 *np.*
3	Sept. 29 "	1 5 0	−44 31 38	*vF. S. R.* no *B* * near *vF* one *f.*
4	" 29 "	1 53 4	−33 31 27	*pB. vS. R. BM.* 10*m* * *v* close *Sp.*
5	" 29 "	2 5 0	−33 25 0	*vF. vS. eE.* nearly 0° *F** *p.*
6	" 29 "	2 58 28	−39 52 38	*eF. pS. R. FD***Si* point to it.
7	" 27 "	3 31 0	−34 46 55	*pB. S. eeeE.* a straight hair-like line 90°. See note.
8	" 29 "	4 8 45	−33 7 51	*eF. vS. R. BM.* 10*m* * close *S.*
9	" 29 "	4 16 30	−31 41 42	*eeF. pL. R.*
10	Aug. 3 "	19 53 30	−38 47 38	*vF. S. R.* 8*m* **f* 90°, *p* of 2 same parallel.
11	" 10 "	19 54 00	−38 47 38	*vF. S. R.* 8*m* **f. f* of 2.
12	July 8 "	20 0 0	−48 35 50	*B. cE. vS.* stellar *f* of 2.
13	Sept. 23 "	20 10 59	−41 53 24	*vF. CS. R.* no *B* * near.
14	" 16 "	20 24 25	−36 39 15	*vF. CS. R.* several *pBstS* and *f.*
15	" 17 "	20 40 25	−38 50 35	*eeF. pS. R.*
16	" 15 "	21 1 31	−30 26 30	*eeF. pS. R. F** near *f* 90°.

No.	Date.		R. A.			Decl.			
			h	m	s	°	′	″	
17	"	17 "	21	41	0	−35	21	58	*vF. vS. R.*
18	"	17 "	21	42	0	−35	27	0	*vF. pL. R.* not 7130 or 7135. *Sp* of 2.
19	"	17 "	21	43	30	−35	22	10	*eeF. pL. R. 3Bstp = ⊿ nf* of 2.
20	"	27 "	21	49	46	−49	31	52	*eF. pS. R* in line with 2 9^m *stSf.* 7^m * in field *Sf.*
21	"	23 "	22	51	30	−43	59	27	*pB. S. R. mbM.*
22	Oct.	3 "	23	27	45	−45	35	40	*vF. S. R. bet 2st.* 8^m * *Sf.* and 7^m * *Sp.*
23	Sept.	23 "	23	39	25	−43	29	15	*vF. eS. R* stellar.
24	"	25 "	23	42	40	−37	36	53	*eeF. CS. R.* in vacancy.
25	"	25 "	23	52	25	−37	34	52	*pB. CS. eE.* 1 * near *Sf.*

NOTES.

This list, the 4th issued from this Observatory amounting to 130, are as will be seen all southern nebulæ. They with a few exceptions are very faint, though some are bright enough to belong to Herschel's class I, which not having been previously seen, shows that the southern sky has not been as thoroughly searched over as has been the northern, including that portion of the southern accessible to Sir Wm. Herschel and Lord Rosse.

Note to No. I = G.C. 27 also N.G.C. 55, is with its associated companion a very remarkable nebula. I am at a loss what to think of it, whether it is all one, the preceding half very, very bright, very large exceedingly elongated, the following half exceedingly, exceedingly faint equally as large and still more elongated, or, if they are two distinct nebulæ, one partly overlapping the other. If single it is curved, if double they are inclined to each other. I am inclined to think they are two distinct nebulæ, one reason being that the brighter following end ends sharply, which would hardly be the case if the brighter merged into the fainter. The nebula was discovered by Dunlap but I doubt if he saw the fainter. As Sir John Herschel does not mark it with the sign a very remarkable or even a remarkable object as he often did, lends plausibility to the idea that the fainter was not even seen by him. As however it has been illustrated a reference to that would decide the matter at once.

No. 7. This at least in one respect is the most singular nebula I have ever seen. I doubt if the entire heavens afford a similar example. If the reader will cut off a short piece of fine bright brass wire and hold it up sidewise to the sky he will form by looking at it a very correct idea how it appeared to me. The line was certainly nebulous. It must be a thin nebulous disk seen exactly edgewise.

General Catalogue 383 does not exist, and must be struck out. Sir John Herschel makes both 380 and 383 of equal brightness, and the places given would place both well within my field of 31′

in diameter, power 132. I made a long and thorough search for 383, and would have found it if there, had it been three times fainter than 380 which is an easy object.

ON THE STUDY OF ASTRONOMY AND ON EDUCATIONAL IDEALS.*

T. J. J. SEE.

Astronomy is the most ancient of the Sciences, and the great space of time over which its development stretches, in periodic but yet unbroken continuity, renders it particularly instructive as to the processes involved in the progress of knowledge. This science thus has at once a peculiar philosophical and educational interest, and the study of its history is highly inspiring to the thoughtful student. The educational interest attaching to the science may be embraced under two heads:

1. The uplifting influence of a study possessed of the glorious history of the development of the true system of the world, strongly impressing on the individual the possibility of knowledge, and the moral inspiration springing from intellectual association with the great and good men who have made these discoveries, which to the end of time will be justly regarded as veritable monuments of the human race.

2. The rigid discipline and sustained effort required for unfolding the profound mysteries of this sublime science, and the unsurpassed moral effect of the noble labor involved.

Astronomy thus has at once an inspiration not inferior even to the writings of Plato the divine, and is bearer of the hope born of the most triumphant course of discovery in human history; and I say that a science such as this is pre-eminently suited for educational purposes. To render this clear, let us ask what class of studies is desirable in educational work? The easy and flimsy subjects which require the least effort, moral and intellectual, or those requiring the full exertion of the powers bestowed on the individual by the bounty of nature? The answer to this question ought not to be difficult. The mechanic does not acquire skill by idleness, the athlete does not gain strength by inactivity, nor does the undisciplined soldier willingly endure the hardships of a campaign; the perfection of the athlete depends on his unceasing

* Address delivered by invitation before the Territorial Teachers' Association of Arizona, Oct. 21, 1897.

practice, the skill of the laborer upon his exertion, and the discoveries of the man of science are the reward of rigorous and ceaseless research. What leads to the acquisition of proficiency directs also the road to happiness; for happiness cannot be sought like riches, but must be the incidental reward of some activity directed to good and noble ends. Therefore, since education ought to have regard to the happiness of the individual, we may affirm that only the difficult studies—subjects which require long and ceaseless effort—can give proficiency by the development of the intellectual powers, and the moral condition of happiness—the consciousness of a good and noble activity.

Astronomy and the other physical sciences, then, are well suited, yea even preeminently adapted to the demands of true education; for Mathematical Astronomy, Mathematical Physics, Mathematics, Mechanics, Physical Chemistry and Physical Geology must be accounted the most difficult and the most austere of the Sciences, and they are therefore especially suited to the development of intellectual strength, and of a noble disposition.

There is also a philosophical side to the question of the cultivation of these exact sciences. It is only by the methods of mathematical research that the deep questions of Astronomy, Physics and Geology can be definitely settled; the only final and convincing proof is a mathematical demonstration based upon known and certain postulates conformable to the actual phenomena of nature. The man of science who is skilled in mathematics is alone capable of exploring the past and future history of the universe, and of discovering from known mechanical laws now in operation phenomena which will certainly take place, but which mortal eye will never witness.

The historian of the Sciences also recognizes that the one condition of scientific progress is definite and exact ideas applied to well ascertained facts; and nothing is so essential to definiteness of thought as a mathematical test. It is chiefly by this criterion that the capable geometer is enabled to reject, on first sight, numerous vague hypotheses proposed by speculative persons for the explanation of natural phenomena, and to distinguish others which are worthy of investigation and extension. Thinkers in some ages have pursued definite and exact methods and consequently the sciences have advanced; in others they have been influenced by arbitrary *a priori* ideas, and by mystic and vague considerations, and in such times knowledge either stagnated or retrograded, as happened in the decline of the Roman Empire, and for many subsequent centuries. Those who desire to exam-

ine carefully this large subject of the progress of knowledge and the conditions by which it is influenced, may be referred to Whewell's History of the Inductive Sciences (D. Appleton & Co.); a work of the highest philosophical excellence, which should be read by every teacher in the land.

When we compare these ideals with the standards now in use in this country we must confess some disappointment—but perhaps it is not worse than that which we experience on comparing the politicians of this day with the statesmen of the time of George Washington. Degeneration in the ideals of education, as in the standards of politics, has certainly taken place, and in both cases is traceable mainly to one cause—demogogy, or the effort to please the multitude even by the sacrifice of honor and principle. Some twenty years ago a certain class of educators undertook to win the ear of public favor by declaring that they had discovered a royal road to learning—and such a road, during this time, has seemed even more pressing than at any previous period of our history, for invention and concentration of capital has rendered competition intense, and only loudened the cry for practical, money-making things, in education and in life generally. The result, in a country where the influence of the multitude is dominant, if not supreme, is that there has been a great "extension" of learning by lowering the standard; and such institutions as Chatauqua have come to hold in the public mind the place of real Universities, of which we are sorely in need, if indeed we have one between the two oceans. A part of this retrograde movement consisted in the introduction of popular fads, such, for example, as the so-called science of Sociology and a multitude of theories of Pedagogy. The fallacy of the theories of Pedagogy, on which so much time is wasted, has been repeatedly demonstrated by many able writers, and is probably known generally throughout the country. Yet if any person be disposed to dispute this view, I would fain ask him to name any considerable number of eminent authors, thinkers, investigators or discoverers, of any age or country, who have given their adherence to these views—I myself am unable to point to one in the annals of science.

The case of Sociology is a little different from that of Pedagogy, but is at once disposed of without equivocation. It is admitted by sociological writers, from Herbert Spencer down, that very little or nothing is known of the absolute laws of human society; that what has been observed, in different ages and different countries, is to be explained mainly by tradition, fashion, cir-

cumstances, instinct, religious belief, national aspiration, or race prejudice; and what has been true in the past certainly will be true of the races of the future. It will doubtless be argued that what is not known should be investigated, and no one will deny the importance of sociological questions; yet even the least skilled in scientific investigation must admit that what is not known can not be taught; that the teacher cannot give his student what neither he nor his master, the investigator, possesses. Therefore, from an educational point of view, Sociology, which may be interesting as a descriptive account of human events, has not the least disciplinary value; and its introduction into our college courses is not only unwise, it is an educational blunder of the most glaring kind. Its introduction, however, is hardly to be ascribed to the belief in educational circles that such pseudo-science has any real value; it is rather to be explained by the political methods adopted by certain educators to win favor with a people who are burdened by oppressive and unnatural economic conditions. Therefore let no one be led into the belief that Sociology is a proper educational subject, because a few universities, reputed to be great and progressive, have added it to their curricula. The study of Sociology as a new branch of what may some day become a science is entirely right and proper, but mature men of science must do this work, not young students who are seeking educational discipline in what is known. We may add that even if Sociology were a science, it would hold a low place in the high curriculum of learning; for such knowledge as it would give its devotees would share sparingly in divine ideals, and consecrated rather to the humble conditions prevailing in the world, than to those which ought to exist, its general effect upon the mind would be oppressive rather than elevating, even if there appeared a ray of hope in the possible betterment of the conditions of mankind.

In addition to the introduction of such fads as sociology, pedagogy and a smattering of biology, a great harm has resulted from the unreasonable reaction against the classic languages. It is easy for those who have never had a true university training, who have had their ideas of culture shaped by the commercial fashion of this particular country, and the whirl of turmoil in which our people are carried along, to pursuade themselves that we are now quite beyond the need of Latin and Greek; that the places of the classic languages can be and ought to be supplied by the more practical study of French and German. This demand for practical and useful things is just as erroneous as the one pre-

viously mentioned; it loses sight of the fundamental principal in education, viz: That the sole purpose of education is discipline in thinking, and the cultivation of attachment to the noble and the ideal. That the classic languages afford a better discipline to the mind than any other is generally conceded by the best authorities and proved by the experience of every age. In our own time we find the most eminent savants of Germany of this opinion; and in England, Lord Kelvin, the ex-president of the Royal Society, who for fifty years has engaged in physical research and is easily the greatest man of science since Laplace, comes out squarely against the making of Greek optional in the University of Cambridge, and the proposition is voted down in the Senate by an overwhelming majority. Is it likely that on this great question, such mature and intelligent judgment can be wrong, and that of the inexperienced and the unclassic teacher right? Training in the classic languages affords the desired mental discipline, and stimulates a careful and accurate use of language and of thought; which, as has been said before, is the essential condition of scientific progress. I advocate therefore a return to the study of the classics as the best and safest basis for the advancement of science; besides, the ideals and the philosophy and the poetry of the ancients, far removed from the corrupting clamors of our time, exert the most noble influence upon the mind, and from that point of view alone Latin and Greek should be maintained as the basis of linguistic study.

I am aware that these views are antagonistic to those held by many persons occupying chairs in our universities and colleges, and that a considerable number of persons without a classic training have succeeded in accomplishing *something* as investigators; yet I still wait to see one man of the highest type who has not been so prepared. And if the highest and best be not possible without the classics, what teacher or youth worthy of the American name would depart from them to take a pretended royal road to learning?

Thus, as has been intimated before, I am willing to be counted among those who believe that educational subjects should be sifted and carefully selected, and only the most rigid, the most essential, and the most noble allowed a place in the ideals set before youth; for power is developed only by rigid discipline, and high character can hardly be produced except by the influence of the good and the noble.

This leads me to say that in my view there are two purposes in education, one the formation of character, the other the acquisi-

tion of knowledge. If the family had the weight in society it once had, a considerable part of the first could be accomplished at home; under existing circumstances the selection of teachers becomes more and more important. Personages of the type of General Lee and John Quincy Adams are hardly to be expected except from the noble environment of great families; yet if such types were more general the moral effect on the community could easily be foreseen. On account of this sacred character and great influence of the teacher, more care in the selection of the teacher is a great desideratum of our time.

The unfortunate lowering of the collegiate standard, previously alluded to, has been accompanied by another calamity equally or more deplorable. I refer to the recently introduced, but not yet universal, custom of nominating college and university presidents from a class of persons distinguished for something besides their scholarship and their devotion to truth. That the policy of choosing an administration which gives what is called a business and numerical success is really a failure, will be evident by recalling the case of Washington and Lee University under the presidency of General Lee. The great attendance of young men at the college during this period can be assigned to nothing whatever except the nobility of Lee's character, and the unfeigned esteem inspired by the example of this great and good man among the people. But as such men seldom exist, and still more rarely get the presidency of universities, the people have little opportunity of comparing their work with that of the so-called progressive educator, and hence in recent times the importance of having the best man at the head has not been sufficiently considered.

I have spoken briefly of some of the dangers to American education; let every thoughtful person, who labors for the honor and welfare of the country be vigilant in his search for those institutions which deserve support, and it is not difficult to foresee that in the course of time some abuses now very apparent will be reformed.

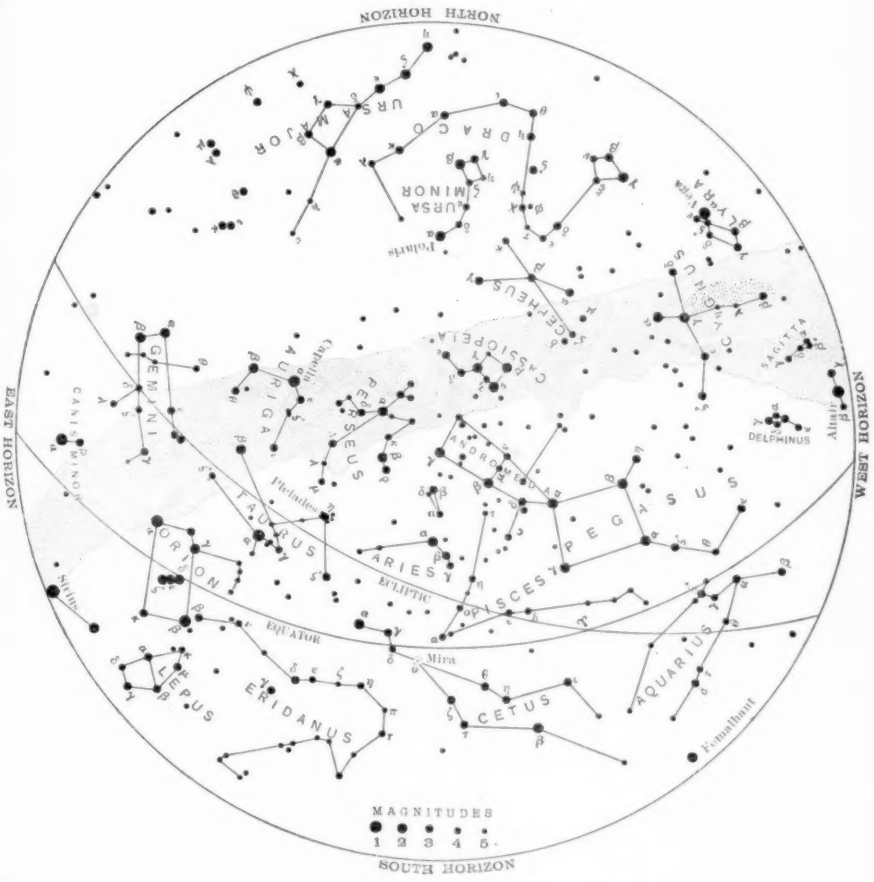
Fortunately the divine science of astronomy is rich in high and noble ideals, and in every age has exercised a good educational influence. Few sciences can claim such an array of geniuses and such noble characters. Plato and Ptolemy, Copernicus and Galileo, Newton and Laplace, Herschel and Gould are the spiritual, educational and scientific benefactors of mankind: their luminous examples are lights to every searcher after truth, and will continue to shine through all time.

LOWELL OBSERVATORY,
Flagstaff, Arizona, Oct. 15, 1897.

PLANET NOTES FOR DECEMBER.

H. C. WILSON.

Mercury will be evening planet during the month and will be visible toward the southwest a half hour after sunset, from the 15th to the 25th. Greatest elongation, 20° east from the Sun occurs on the 20th.



THE CONSTELLATIONS AT 9 P. M., DECEMBER 1, 1897.

Venus will be morning planet, visible toward the southeast for an hour before sunrise. Venus is moving eastward, but only a little more rapidly than the Sun,

so that her apparent distance from the great luminary is decreasing slowly. Her motion with reference to the other planets in the same vicinity is much more rapid. She passes by *Uranus* on the 8th, conjunction occurring at 8 a. m.; by *Saturn* on the 12th, conjunction at 2 p. m.; and by *Mars* on the 30th, conjunction at 5 p. m. central standard time. As these planets are all within about 15° of the Sun and at a low altitude in the morning, their position is unfavorable for observation.

Jupiter is in the constellation Virgo, seen toward the east after midnight. The best time for observation will be just before sunrise, when Jupiter will be well up toward the meridian. Jupiter will be in conjunction with the Moon Dec. 18, at 1:30 a. m. and at quadrature, 90° west from the Sun, Dec. 30.

Neptune will be at opposition, Dec. 12, and may be observed with a telescope during the greater part of the night, the best hours being those near midnight. *Neptune* is near the 3rd magnitude star ζ Tauri at the tip of the Bull's horn. The planet is about two degrees west and three quarters of a degree north of ζ and about 25′ east of the sixth magnitude star *o* (Omicron). During the month Neptune will move slowly westward, passing 4′ to the south of Omicron on the 15th.

The Moon

		Phases.	Rises. Local Time.	Sets. Local Time.
Dec.	8	Full Moon	3 40 P. M.	8 8 A. M.
	16	Last Quarter	10 58 "	11 33 "
	23	New Moon	7 41 A. M.	4 11 P. M.
	30	First Quarter	11 13 "	12 52 A. M.

Occultations Visible at Washington.

Date 1897.		Star's Name.	Magnitude.	IMMERSION. Washington M. T. h m	IMMERSION. Angle f'm N pt. °	EMERSION. Washington M. T. h m	EMERSION. Angle f'm N pt. °	Duration. h m
Dec.	5	26 Arietis	6.0	7 48	40	9 10	260	1 22
	12	δ Cancri	5.7	8 4	50	8 40	‡34	0 36
	17	*q* Virginis*	5.7	11 3	145	11 46	264	0 43
	18	75 Virginis‡	6.0	13 56	48	14 15	8	0 19
	21	B.A.C. 5314*	5.7	4 13	118	4 58	243	0 45
	22	B.A.C. 5800*	7.5	5 31	117	6 11	230	0 40
	25	*o* Capricorni‡	6.2	6 37	28	7 23	279	0 46
	27	δ Aquarii	4.4	5 54	30	7 0	258	1 6
	27	B.A.C. 7804*	6.2	9 45	136	10 0	170	0 15

* Whole occultation below the horizon of Washington.
‡ Immersion below the horizon of Washington.
‡ Emersion below the horizon of Washington.

VARIABLE STARS.

J. A. PARKHURST.

ANDERSON'S VARIABLE IN COMA. (See September number, page 270). This star has not changed enough since observations began in August, to afford certain confirmation of its variability. It was observed here in the evening till Sept. 14, at which time it seemed a little fainter than on August 1; but was so low in the west that I could not be certain of a change. It was observed in the morning Oct. 25, and was apparently a little brighter than in September. It will

be remembered that Anderson's estimated place, $12^h\ 23^m.0 + 32°\ 17'$, did not exactly agree with the micrometer measures which gave $12^h\ 23^m\ 1^s.0 + 32°\ 18'\ 19''$, 1855. Rev. Anderson writes me under date of Oct. 19, "You have undoubtedly fixed on the right star, for in deciding on the minute of declination given in A. N. 3433 I felt that the number (17) erred if anything on the side of smallness." It is therefore quite possible that the star passed a rather flat maximum in September, and has begun to rise slowly. It is now in position for morning observation and should be watched.

Minima of the Variable Stars of the Algol Type

[Given to the nearest hour in Greenwich Mean Time.]

U CEPHEI.

1898.

	d	h
Jan.	4	12
	9	11
	14	11
	19	11
	24	10
	29	10
	31	22

ALGOL.

1898.

Jan.	8	21
	11	18
	14	15
	17	12
	20	9
	31	20

λ TAURI.

1898

	d	h
Jan.	2	16
	6	15
	10	14
	14	13
	18	11
	22	10
	26	9
	30	8

R CANIS MAJORIS.

1898

Every 8th min.

$P = 1^d\ 3^h\ 16^m$

Jan.	9	9
	18	11
	27	13

S CANCRI.

1898

	d	h
Jan.	17	12

S VELORUM.

1898

Jan.	1	8
	7	7
	13	5

δ LIBRAE.

1898

Jan.	4	16
	11	16
	18	16
	20	23
	25	15
	27	23

U CORONÆ.

1898

	d	h
Jan.	6	19
	13	17
	20	15
	27	13
	30	23

U OPHIUCHI.

Every 10th min.

$P = 20^h\ 8^m$

Jan.	2	23
	11	8
	19	17
	28	3

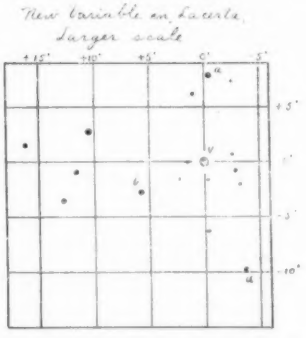
W DELPHINI.

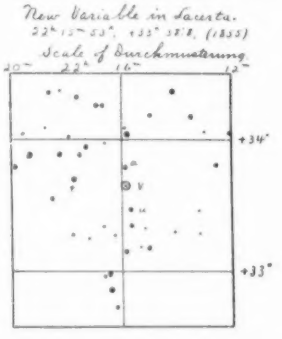
1898

Jan.	14	18

The above ephemeris was computed for POPULAR ASTRONOMY directly from the elements given in Chandler's Third Catalogue and supplements. All the minima are given which occur in the night hours in American and European longitudes when the star is above horizon, except for R Canis Majoris and U Ophiuchi.

NEW VARIABLE IN LACERTA. In *Astronomische Nachrichten* No. 3447 Professor Deichmüller announces the variability of DM + 33°,4489. This star was observed as 9.0 magnitude, 1856 Aug. 10 and 24. It was on the programme





of the Leyden zones, but could not be seen with the meridian instrument 1871 Aug. 15, 31, Sept. 5 or 1893 Aug. 13, though a star, not in the DM., 29ᵐ follow-

ing and 0′ 5 south of the missing star, was twice observed. This star Professor Deichmüller estimates as 9.65 magnitude. On looking for the missing star at Bonn, 1897 Sept. 11, Professor Deichmüller found it 8.9 magnitude. I have observed this star since Oct. 9 and have measured the field with the filar micrometer with the following results.

COMPARISON STARS FOR DEICHMULLER'S NEW VARIABLE IN LACERTA.

Magnitudes only approximate, for identification.

	Co-or. from V. R. A.	Decl.	Mag.		Co-or. from V. R. A.	Decl.	Mag.
	s	′			s	′	
u	− 3.8	− 18.2	− 9.9	9.7	*r* + 1.5	+ 7.4	0.0	12.0
o	− 3.2	− 15 3	− 2.1	11.5	*q* + 2.4	+ 11.5	− 1.6	12
n	− 2.9	− 14 0	− 0.8	10.7	*b* + 5.9	+ 28.5	− 2.9	9.7
g	− 2.6	− 12 5	+ 7.4	11.1	*e* + 10.5	+ 50.8	+ 2.9	9 4
m	− 2.5	− 11.9	+ 0.7	11.7	*k* + 11.6	+ 55.7	− 0.8	10.6
p	− 0.4	− 2.0	− 1.7	11.5	*l* + 12.9	+ 62.0	− 3.5	10.1
a	− 0.3	− 1.4	+ 7.8	9.0	*h* + 16.2	+ 77.9	+ 1.5	10
s	− 0.4	− 1.8	− 6 2	10.3	*t* + 22.2	+ 106.9	+ 1.4	8
f	+ 1.0	+ 4.7	+ 6.1	9.9				

It should be noticed that my comparison star *b* corresponds closely in R. A. with Deichmüller's star, but is 2′.9 south of the variable, instead of 0′.5. It is thus possible that I have not correctly identified the variable, as the star I have observed as such, has not changed in light from Oct. 9 to the present date, remaining about 1 step brighter than *a*, and 3 steps brighter than *b*.

MIRA. This star is now quite bright, being easily recognized with the naked eye. According to its behavior for some years past, the maximum would not be expected till early in December. If this proves to be true, it will probably become brighter than usual. The maximum will be past early enough so that the descending branch of the light curve can be observed more completely than for several years.

THE DURCHMUSTERUNG CHARTS.—One of the most useful results of the astronomical conferences connected with the dedication of the Yerkes Observatory was the movement looking towards the publication of a new edition of these valuable charts. The matter was given in charge of a committee, consisting of Professor Pickering, of Harvard, Father Hagen, of Washington, and Professor Snyder, of Philadelphia. This committee reported the prospects as good for having the charts ready in a year or a year and a half. With these and Hagen's Atlas (for which the observations are nearly completed) the work of identifying and observing variable stars will be much facilitated.

1897, Nov. 8.

COMET NOTES.

Comet *b* 1897.—This comet has already become so faint that it is impossible to get a good measure of its position. The nucleus is entirely invisible and the whole comet is a mere faint and formless glow about 3′ long and 1′ wide, without a sufficient condensation in any part for an accurate bisection, and wholly invisible with the slightest illumination of the micrometer wires. It was seen with the 16-inch telescope at Northfield on the nights of Nov. 18 and 23, and occupied very nearly the position indicated by our ephemeris published last

month. Two faint stars which lay within the glow of the comet on the 18th will furnish an approximate determination of the position, provided the weather permits us to determine the place of the stars.

A revision of the elements given last month by Miss Young and the writer yields the following results:

$$\left.\begin{aligned} T &= \text{Dec. } 8.9216, 1897, \text{ Gr. M. T.} \\ \omega &= 66^\circ\ 10'\ 11'' \\ \upsilon &= 32\ \ 4\ \ 9 \\ i &= 69\ \ 37\ \ 21 \end{aligned}\right\} 1897.0$$

$$\log q = 0.131858$$

Residuals, observed—computed: $\Delta\lambda \cos\beta = -2''$; $\Delta\beta = -2''$.

COÖRDINATES FOR THE EQUATOR.

$$x = r\,[9.938187]\sin(168^\circ\ 28'\ 34'' + v)$$
$$y = r\,[9.696962]\sin(168\ \ 2\ \ 31 + v)$$
$$z = r\,[9.999996]\sin(\ 78\ \ 22\ \ 5 + v)$$

D'Arrest's comet is too faint to be observed with small telescopes.

Elements and Ephemeris of Comet *b* 1897 (Perrine).

The following elements have been based upon Mt. Hamilton observations of Oct. 16, 24 and 31:

$$\left.\begin{aligned} T &= 1897 \text{ December } 8^d.84714 \\ \omega &= 66^\circ\ \ 5'\ \ 42''.2 \\ \upsilon &= 32\ \ 4\ \ 4\ .9 \\ i &= 69\ \ 37\ \ 40\ .9 \end{aligned}\right\} \text{Ecliptic and Mean Equinox of 1897.0}$$

$$\log q = 0.132056$$

The following are the residuals for the middle place:

Obs. — Comp.	$\Delta\lambda' \cos\beta'$	$+4''.1$
	$\Delta\beta'$	$+4\ .3$

EPHEMERIS FOR GREENWICH MEAN MIDNIGHT.

1897	True α	True δ	log r	log Δ	Br.
	h m s	° ′			
Nov. 29.5	18 12 28	+ 56 34.0	0.134	0.041	0.72
Dec. 1.5	11 4	55 25.1			
3.5	9 54	54 21.0	0.133	0.058	
5.5	8 56	53 21.3			
7.5	8 5	52 25.9	0.132	0.074	0.63
9.5	7 22	51 34.3			
11.5	6 45	50 46.6	0.132	0.089	
13.5	6 14	50 2.4			
15.5	5 46	49 21.3	0.133	0.103	0.55
17.5	5 21	48 43.3			
19.5	4 59	48 8.4	0.135	0.116	
21.5	4 38	47 36.3			
23.5	4 18	47 7.0	0.138	0.127	0.48
25.5	4 0	46 40.2			
27.5	3 40	46 15.8	0.141	0.137	
29.5	3 20	45 53.5			
31.5	18 3 0	+ 45 33.9	0.145	0.145	0.43

The comet has changed much in its appearance since discovery. For the first few days it had a strong condensation in the head and a decidedly stellar nucleus fully as bright as 12th magnitude. These features were easily seen with the 12-inch refractor and were very conspicuous in the large telescope. By October 30 the nucleus had entirely disappeared in the 12-inch telescope and on October 31st

nothing of it was to be seen with the 36-inch telescope. The comet during this interval had lost much of its light, probably one half. It now had no characteristic head, being simply a streak of nebulous matter about 3′ long by less than 1′ wide, surrounded by a fainter nebulosity whose limits were a little better defined at the end where the head had been.

Its theoretical brightness should have been a little greater on Oct. 31 than at discovery, but as just mentioned it was only about one-half as bright.

A careful search for it on the evening of November 7th (in bright moonlight), made with the 36-inch telescope failed to show it. C. D. PERRINE.

Lick Observatory, University of California.
November 8, 1897.

Ephemeris of Winnecke's Periodic Comet.—In *Astronomische Nachrichten* 3447 Mr. C. Hillebrand gives elements and ephemeris of Winnecke's Periodic Comet for the coming apparition. The comet is due at perihelion March 20, 1898, but will be more favorably situated for observation between the middle of December, 1897, and the middle of February, 1898. It should be looked for in the morning about an hour before sunrise. The comet's apparent path among the stars extends southeast and eastward through Virgo, Libra, Scorpio, Sagittarius and Capricorn. Winnecke's comet is never visible to the unaided eye and during this month will be faint if seen with the aid of a telescope.

ELEMENTS.

	Oct. 26, 1897.	March 15, 1898.	
M	= 335° 24′ 26.7″	359° 3′ 52.0″	
π	= 274 14 33.3	274 14 39.0	1900.0
ν	= 100 53 34.3	100 53 11.5	1900.0
i	= 16 59 34.4	16 59 33.8	1900.0
φ	= 45 37 35.6	45 37 14.1	
μ	= 608″.3483	608″.5559	

EPHEMERIS.

		R. A.			Decl.		log r	log Δ	1 : $r^2\Delta^2$
		h	m	s	°				
Dec.	5	13	51	12	+ 2	28.9	0.23195	0.33500	0.073
	9	14	2	20	1	36.3	0.22193	0.32203	0.082
	13		13	52	+ 0	42.8	0.21164	0.30889	0.091
	17		25	49	− 0	11.5	0.20109	0.29561	0.102
	21		38	14	1	6.6	0.19028	0.28225	0.113
	25	14	51	6	2	2.3	0.17921	0.26885	0.127
	29	15	4	28	− 2	58.6	0.16788	0.25550	0.142
Jan.	2		18	24	3	55.3	0.15629	0.24228	0.160
	6		32	53	4	52.3	0.14446	0.22929	0.179
	10	15	47	58	5	49.3	0.13242	0.21659	0.200
	14	16	3	40	6	46.1	0.12016	0.20432	0.224
	18		20	0	7	42.1	0.10773	0.19259	0.251
	22		36	59	8	37.0	0.09518	0.18151	0.280
	26	16	54	30	9	30.3	0.08256	0.17122	0.311
	30	17	12	49	− 10	21.3	0.06993	0.16184	0.344

GENERAL NOTES.

All subscribers are requested to notice particularly that volume five of this publication does not end with this, the December number. The issues for January and February, 1898, also belong to it. The February number will contain the

index to the volume. The sixth volume will begin with March and end with December, 1898. Subsequent volumes will run even with the calendar years to which they respectively belong.

Mr. D. Flanery, of Nashville, Tenn., has been much interested in variable star observations in recent years; and he has been doing good, faithful work on some of the hard ones. He reports that R Leonis passed its maximum October 19. He expresses the hope that some western observers have been following that star lately. He says Mira (*o* Ceti) reached 3.4 magnitude on Nov. 7, 1897.

A Brilliant Meteor.—Meteors in the Telescope.—A brilliant meteor was observed here on the morning of Oct. 28, at 5:35 A. M., Eastern Standard Time. The estimated positions of the ends of the trail are:

Beginning,	$\alpha = 7^h\ 40^m$	$\delta = -35°$
Ending,	7 30	−39

I was facing north when it appeared. Noticing a bright light flashing over the landscape, I turned quickly and saw a beautiful meteor of a blue or green color moving directly away from ρ Puppis, in a southwesterly direction. When near the end of its path, a small solid portion shot ahead of the debris, producing a short slender trail.

The trail was 4° or 5° in length, and 15′ or 20′ in width, and lingered nearly one minute.

Considering its nearness to the horizon, and the fact that it was seen through a thin fog, it was a very bright meteor.

On nearly every night when observing, since Feb. 24, I have seen one or more meteors with the four-inch telescope equipped with an eyepiece having a power of 18, and a field 2° in diameter. The average number seen was one or more per hour. The most of them were faint, and only one left a visible trail, which vanished in three or four seconds. Several were seen at the beginning of their paths, and were very faint, but rapidly increased in brightness as they shot across the field, looking exactly like Barnard's photographs in the October number of this magazine. ZACCHEUS DANIEL.

Hawthorn Pa., 1897, Nov. 5.

November Meteors.—Cloudy weather at Northfield made observation of the Andromedes for this year wholly impossible. This was a keen disappointment, for it is very desirable to get all the records possible of the behavior of this notable stream several years before and after 1899.

From a pamphlet bearing title "The Great Meteoric Shower of November" prepared by W. F. Denning of England, written for the *Observatory* some months ago, we take the following statement referring to the return of the Belids during the year 1897. He says:

"In 1864, (two years before the maximum of 1866), a grand display of meteors was witnessed from the deck of a ship off Malta on the morning of November 13, and meteors were conspicuously numerous on the same morning in America. We are therefore entitled to expect a pretty abundant display in 1897, and should it prove a return of the same group which supplied the meteors of 1864, it will probably appear in the morning hours of Nov. 14. But the Earth will intersect a point of the meteoric orbit rather farther in advance of the comet than it did 1864, and so the exhibition of 1897 is not likely to equal the former, unless,

indeed, the richer part of the stream has lengthened out in the interval of 33 years which is quite possible. The really dense part of the system which furnished the brilliant European display of 1866 (maximum Nov. 13, $13^h\ 10^m$) and the equally imposing American shower of 1867 (maximum Nov. 13, $22\frac{1}{2}^h$) is not likely to be visible in England, as the Earth will be centrally involved with it on the 14th at midday. In America something of it may possibly be seen just before sunrise on the 14th. The Moon will be full on the morning of the 9th, and will therefore be gibbous on the 14th, rising at $7^h\ 55^m$ at Greenwich, and being visible in Gemini during the whole night afterwards. The prospects are therefore by no means good, but a close watch should be maintained on the mornings of the 14th, 15th and 16th, for if the atmosphere be clear, meteors will be seen to be frequent and fine ones may appear every now and then."

From a private letter by Professor E. E. Barnard, of Yerkes Observatory, we gather the following observations:

Nov. 13 Broken from $5^h\ 50^m$ to $7^h\ 30^m$ P. M. No meteors seen. From $7^h\ 30^m$ to $18^h\ 30^m$ densely cloudy and raining.

Nov. 14. Broken from 6^h to $6^h\ 30^m$ P. M. and again from $8^h\ 45^m$ to 9^h P. M. when partly clear. No meteors seen. Densely cloudy and raining all the remainder of the night until $18^h\ 30^m$. The watch was continued all night on each of these days to the hour last named. Professor Barnard had made careful preparations to photograph the meteors with four different cameras, and of course was greatly disappointed in consequence of unfavorable sky.

Spectrum of a Meteor.—The photographs of a spectra of the stars taken at the Harvard College Observatory as part of the Henry Draper Memorial differ in two respects from those ordinarily taken elsewhere. Instead of using a spectroscope with a slit, in which but one star is photographed at a time, a large prism is placed over the object glass of the telescope and thus spectra of all the bright stars in the field of view are obtained. The number of stars photographed simultaneously is still further increased by substituting for the object glass a portrait lense like that used by the photographers, only larger. The field of view is in this way increased from two degrees square to ten degrees square, and a photograph is obtained of the spectra of all the brighter stars in this large region. Many thousand plates, covering the entire sky, have been taken in this way at the Cambridge and Arequipa Stations of this Observatory. All have been examined by Mrs. Fleming and, as a result, numerous remarkable objects have been discovered. One of the latest is the spectrum of a meteor which has thus been photographed for the first time. Since it is impossible to foresee when the bright meteors will appear, or what path they will follow, a photograph will be obtained only when one happens to cross the field of the telescope. A number of trails of meteors have been obtained, both here and elsewhere, when charts of the stars were photographed, no prism being used. When the prism was in place no meteor bright enough to leave a noticeable trail has heretofore been photographed on the many thousand plates examined. At about 11 P. M. on June 18, 1897, however, when the 8 inch Bache telescope at Arequipa was directed toward the constellation Telescopium, a bright meteor appeared in right ascension $18^h\ 19^m$, declination $-47°\ 10'$, and passed out of the field at right ascension $18^h\ 29^m$, declination $-50°\ 30'$. The spectrum consists of six bright lines whose intensity varies in different portions of the photograph, thereby showing that the light of the meteor changed as its image passed across the plate. The approximate wavelengths of these lines are 3954, 4121, 4195, 4344, 4636, and 4857, and their in-

tensities are estimated as 40, 100, 2, 13, 10, and 10, respectively. The first, second, fourth, and sixth of these lines are probably identical with the hydrogen lines Hε, Hδ, Hγ, and Hβ, whose wave-lengths are 3970, 4101, 4341, and 4862. The fifth line is probably identical with the band at wave-length 4633, present in spectra of stars of the fifth type and forming the distinctive feature of the third class of these stars. The third line, which is barely visible, is perhaps identical with the band at wave-length 4200, contained in these stars (Astron. Nach. 127, p. 1).

It will be noticed that of the four hydrogen lines in the spectrum of the meteor, Hδ is the most intense. This is also the case in the spectrum of *o* Ceti and of many other variable stars of long period. In some variables of long period Hδ and Hγ are equally intense, while in others Hγ is the more intense. In some stars of the first type in which the hydrogen lines are bright, like γ Cassiopeiae, the line Hβ is much more intense in the photographic spectrum than any of the other lines, while in the spectra of stars like P Cygni and η Carinæ, Hδ, Hγ, and Hβ are nearly equally bright. These results show an important resemblance between meteors and stars having bright lines in their spectra, and may aid in determining the conditions of temperature and pressure in these bodies. Since bright meteors sometimes appear during the November meteoric shower a special effort will be made here to obtain photographs of them, both trails and spectra, on November 13.

November 8, 1897. EDWARD C. PICKERING.

—HARVARD COLLEGE OBSERVATORY.

Circular No. 20.

The Observatories in Catania and Etna.—An historical account of the origin and work of these observatories is given by Dr. A. Ricco in the October number of *Memorie della Societa degli Spettroscopisti Italiani*. The former is situated in the city of Catania near the foot of Mt. Etna, Latitude north 37° 30′ 13″.2, longitude 1^h 0^m 18^s.93 east from Greenwich. The latter is near the summit of Etna, by the side of the central crater. Both observatories are under the auspices of the University of Catania and are well equipped for astrophysical research. The observatory of Catania possesses a 13-inch visual telescope as well as a twin photographic refractor of the same aperture. A large amount of work has been done there in the line of celestial photography during the last two years, Catania having as her share in the "photographic chart of the sky" the zone from + 47° to + 56° of latitude.

Visitors at the U. S. Naval Observatory.—The *Washington Post* of recent date gave an interesting account of a visit of the Geographical Society to the Naval Observatory. In the report it was stated that there were about 400 visitors present by invitation of those in charge of the Observatory, for a look at the Astronomical instruments in the new building and for some views of celestial objects. The time service was explained, and the telescopes including the great 26-inch equatorial, which was pointed to with just pride as the instrument with which Professor Asaph Hall discovered in 1877 the two minute satellites belonging to the planet Mars.

It was also said, (if the reporters did not go wrong, they sometimes do) that there are only three larger refracting telescopes in the world, two of which are in the United States. This is rather a bad error, in regard to telescope magnitudes in the world.

The following is the number and size of refracting telescopes larger than the Washington instrument:

The Yerkes glass, 40 inches in diameter; Lick, 36 inches; Pulkowa, (Russia) 30; Nice, (France) 30; Greenwich, (England) 28; Vienna, (Austria) 27; and then follows the Washington glass 26 inches and its companion of the same size at the University of Virginia known as the Leander McCormick telescope.

Observations of Meteors.—On Oct. 18, 1897, at 6:58 p. m. Mountain Time, Mr. F. L. L. Hiller observed a red meteor, brighter than the first magnitude, which started close to Zeta Piscis Australis, traveled eastward, passing just north of Fomalhaut, and disappeared about two degrees east of Mu Sculptoris. The length of its path was estimated at twenty degrees; the time of flight was five or six seconds.

On Oct. 28, 1897, Mr. C. P. Fonda saw about 5:15 p. m. a fair sized meteor in N. N. W., its azimuth being about 165°, and altitude about 60°. After traveling some distance, leaving a vivid blue trail, it apparently exploded, producing a ball of blue flame, somewhat larger than the meteor had appeared to be. It was then at azimuth about 135°, and altitude about 45° to 50°.

Each observer was in longitude 105° west of Greenwich, and latitude 39°41′ north. H. A. HOWE.

University Park, Colorado.

The Problems of Astronomy.—We did not have the pleasure of hearing the address by Professor Simon Newcomb, of Washington, at the dedication of the Flower Observatory of the University of Pennsylvania, given on the 12th day of May last on The Problems of Astronomy. However, a brief report of the exercises of that occasion and of the address was given in the next number of this publication by the kindness of friends solicited for it. Recently we have been favored with a pamphlet copy of the address which interested friends have wisely put in this more permanent form. In it we find this reference to the Flower Observatory which gives Professor Newcomb's opinion of the work going on there under the direction of Professor Doolittle:

"The director of this new Observatory has already distinguished himself in the delicate and difficult work of investigating the variation of latitude, and I am glad to see that he is continuing the work here with one of the finest instruments ever used for the purpose, a splendid product of American mechanical genius. I can assure you that astronomers the world over will look with the greatest interest for Professor Doolittle's success in the arduous task he has undertaken. The wise policy of the astronomer of today is to do but one thing, and to do it well, and this little Observatory, small as it is, is finely equipped for this one thing."

October Meteors.—The writer observed on the 27th of October at about 6:40 P. M., a brilliant meteor sweep slowly across the eastern sky. It first became visible in the constellation Perseus, very near Camelopardalus and shot across the sky in a southerly direction, disappearing near the horizon in Cetus. The space of time occupied in its transit was about 5 seconds. WESTON WETHERBEE.

Barre Center, N. Y., Oct. 28, 1897.

Professor Upton at Harvard College Observatory Station, Arequipa, South America.—We have before spoken of Professor W. Upton's

leave of absence from the Ladd Observatory of Brown University, Providence, R. I., for a year in order to do some astronomical work at the Peru station of the Harvard College Observatory located at that place. We had the pleasure of meeting Professor Upton at the Yerkes Observatory conferences in October last, and of learning considerable about the good work being done at the station and something of his part in it. He reports a pleasant and profitable year at Arequipa, and he also said "your former pupil, Mr. DeLisle Stewart, is very much prized there, and I was especially glad to get acquainted with him."

We have no doubt at all but that Mr. Stewart will succeed nobly in the science he has chosen and loves so much.

Observational Astronomy.—We notice that Arthur Mee, F. R. A. S., of England, has recently published a revised and enlarged edition of his book on Observational Astronomy which is spoken of as a practical book for amateurs, containing many maps and illustrations for their guidance in astronomical work. We have not yet seen the book and so can not speak more particularly of it.

Globe Mounting.—We have been recently favored with a sample globe whose mounting has been recently patented. The globe is about ten inches in diameter, and is provided with a motion that nicely illustrates the precession of the equinoxes and the motion of the pole of the celestial equator around the pole of the ecliptic in the long period of 25,800 years, besides many other lesser things shown by ordinary globes. The whole arrangement is so simple in design and inexpensive as to commend it for the use of the class-room very generally.

Mr. Thomas, of Lacon, Illinois, is the patentee. More particular information if desired may be secured from him.

The Great Meteoric Shower of November.—W. F. Denning, F. R. A. S., of England, who has written much for this publication and others of a scientific character in this country and abroad, has recently furnished a number of most valuable articles for the *Observatory* (English) on the great meteoric shower of November. This matter has been reprinted from the *Observatory* in the form of a pamphlet consisting of 52 pages of the size of ours approximately. The tables and illustrations which accompany the text make it a very complete hand book of reference pertaining to the history and chief characteristics of this most notable stream of meteors. We are sure that any astronomer interested in this matter will certainly desire this important information which can probably be secured from Messrs. Taylor and Francis, Red Lion Court, Fleet street, London, at the small price of one English shilling. Since so much interest will be felt in the behavior of this great stream of meteors for the next five or six years, this pamphlet appears as timely help by one fully and ably qualified to speak on a theme he has diligently and successfully studied for many years.

The Great Clock of the Heavens.—On November 7, Dr. Talmage, at the Presbyterian church, Washington, D. C., preached the first of a series of sermons on God everywhere, taking for the theme of this discourse, God among the Stars. In the address he thus refers to the "Great Clock of the Heavens:"—

"What a monstrosity of ignorance that the majority of Christian people listen not to the voices of other worlds, although the Book says, 'The heavens declare the glory of God,' and, again, 'The works of the Lord are great and to be sought out.' How much have you sought them out? You have been satisfying

yourself with some things about Christ, but have you noticed that Paul calls you to consider Christ as the Creator of other worlds, 'by whom also He made the worlds?' It is time you Christians start on a world hunt. That is the chief reason why God makes the night, that you may see other worlds. Go out to-night, and look up at the great clock of the heavens. Listen to the silvery chime of the midnight sky. See that your children and grandchildren mount the heavens with telescope for alpen stock, leaping from acclivity of light to acclivity of light. What a beautiful and sublime thing that John Quincy Adams, the ex-president, borne down with years, undertook at the peril of his life the journey from Washington to Cincinnati that he might lay the corner-stone of the pier of the great refracting telescope, there making his last oration. What a service for all mankind when, in 1839, Lord Rosse lifted on the lawn of his castle eighty miles from Dublin a telescope that revealed worlds as fast as they could roll in, and that started an enthusiasm which this moment concentrates the eyes of many of the most devout in all parts of the earth on celestial discovery. Thank God that we now know where our own world is, bounded on all sides by realms of glory, instead of being where Hesiod in his poetry described it to be, namely: half way between heaven and hell, an anvil hurled out of heaven, taking ten days to strike the earth, and hurled out of earth, taking ten more days to strike perdition:

> From the high heaven a brazen anvil cast,
> Nine days and nights in rapid whirls would last;
> And reach the earth the tenth; whence strongly hurled,
> The same the passage to th' infernal world.

BOOK NOTICES.

Algebra Reviews is a little book of 44 pages, prepared by Edward R. Robbins, Master in Mathematics and Physics at the Lawrenceville school and published by Messrs. Ginn & Co., Boston and Chicago. It is intended to be used only in reviews in the place of the elementary algebra. The plan of presenting new examples in reviews, and such ones as some one other than the regular teacher might choose, without such an aid, is manifestly a good one.

Memorials of William Cranch Bond, Director of Harvard College Observatory, 1840–1859 and of his son, George Phillips Bond, Director of the same Observatory, 1859–1865, by Edward S. Holden, Director of the Lick Observatory, 1897.

The introductory note to this new volume speaks of the relation of the writer, by marriage of his cousin to the younger Bond and the inspiration he himself received when a lad, in visits made to the Harvard College Observatory. Later he was a student at the same Observatory, and he gives great credit to the qualities of mind possessed by the younger Bond shown in the contributions to astronomy whose worth the judgment of later years fully verifies.

No adequate biography has been written of either of the Bonds, and this fact is especially noticeable in the case of the son. So at the request of his daughters the writer undertook the task of preparing such biographical sketches of each as are really needed to complete in this particular the early history of astronomy in America in which these two noble men figured very prominently.

After introductory note, the book is divided into five chapters. The first gives an account of William Cranch Bond, the second is devoted to George Phillips Bond, the third gives extracts from the diaries of George Bond during two visits to Europe in 1851 and 1863, the fourth consists of selections from the correspondence of George Bond, 1862 to 1865, and five is the scientific work of William and of George Bond. A full appendix follows giving a list of the scien-

tific writings of William Cranch Bond and George Phillips Bond which have been compiled by Mrs. Richard F. Bond. The book closes with a list of 190 proper names, embracing a very large number of the most prominent men of science in Europe and America who were acquaintances or correspondents of the subjects of these memoirs.

We have been interested in this new book, not only on account of the full biographical sketches of the Bonds, but, also, on account of the facts and incidents which the writer brings to notice pertaining to the lives of other distinguished men as well. There is always so much of inspiration and help in the real, or even the incidental touch of the lives of great men that the earnest student longs for much of it. The writer certainly knows how to bring out such matter well.

The illustrations are reproductions of some of the drawings of George Bond; Donati's Comet, Oct. 4, 1858, and the Nebula of Orion. The half-tone picture of William Cranch Bond is fairly good, not as perfect in the copy of the book before us as may be in others. Portions of the picture are sharp, other parts are rather weak. We are sorry not to find a picture of George Bond. Fine pictures of illustrious men are widely prized. They are much used and have educational value.

The Elements of Astronomy, by Chas. A. Young, Ph. D., LL. D. Revised Edition with Synopsis and Uranography, pp. 504. Price $1.40.

Our readers everywhere are so well acquainted with the series of text-books on astronomy by Professor Young of Princeton, that it is not necessary to refer to the merits of these books in general. All that seems to be called for now is to notice the changes that have been made in the late revision of his second book in the series known as The Elements of Astronomy. The first edition was issued in 1889, and the revision was completed in June of this year. In the first thirty pages we have noticed only small changes; on page 34 two changes, one a better statement and an omission. On page 44 is a needed paragraph in regard to the variation of latitude. In respect to the form and size of the Earth some minor changes. In regard to the Earth's mass the units of measure are spoken of in late and definite way. This is a help at a difficult point.

In chapter six treating of the Sun is found many important changes. These are in regard to the probable error of the solar parallax, early records of sun-spots, illustration of Wolf's sun-spot numbers, Spœrer's motion of sun-spot belts, Faye's cyclonic theory of spots, telespectroscope for photography, the solar spectrum, Fraunhofer lines, table of elements known to exist in the Sun, reversing layer, helium, photography of spectrum utilizing the *H* and *K* lines and the corona. Several pages are changed and large additions made to bring matters to date. Minor changes only are made in the next three chapters.

In chapter ten which treats of the planets in general, is a new cut showing the paths among the stars of the planets Saturn and Uranus during the year 1897, and a rewritten statement descriptive of the Ptolemaic system. Important changes and additions are made in the matter of Mercury and Venus. Schiaparelli's and Mr. Lowell's views are considered by the author in regard to surface markings and rotation time, and he thinks the views of the last named observer need confirmation. Still more is said when we come to the planet Mars. We notice the flattening at the poles is represented in this edition by the fraction 1/200 instead of 1/220 found in the former text. The "canals and their gemination" claim most attention. Some of Mr. Lowell's drawings are reproduced which show the wonderful net-work of "canals" all over the planet's surface, including that part which is darker than other portions, and which has been thought to be water surface more or less shallow. The author gives nearly a page paragraph relating to the nature and office of the "canals," ending with the statement, "but whatever may be the explanation, there is no longer any doubt, as to the existence of the "canals," nor that they (and other features of the surface) undergo real changes with the progress of the planet's seasons. Their gemination, however, still remains a mystery, and in the report of the Harvard College Observatory for 1896 it is stated that some experiments recently made there throw a good deal of doubt on the objective reality of the doubling.

Some new matter is also added in relation to the temperature of the planet Mars and its habitability. Both of these themes are topics of very great interest to students of astronomy in popular lines.

The *Gegenschein* or counter-glow, so called, deservedly receives attention. It is a wonder that text-books have so long neglected this phenomenon so easy of sight by the naked eye in favoring circumstances.

Jupiter and Saturn, as expected, are passed with little change of matter. The paragraph relating to Saturn's rings, has a few lines of addition referring to Professor Keeler's beautiful spectroscopic confirmation of the meteoric theory of their constitution, made two years ago. From a photograph of the spectrum of the planet and its rings, the particles at the outer edge of the ring were found to be *moving more slowly than those at the inner edge*, the velocities being 12.4 miles per second for the inner, and 10.1 miles per second for the outer, as they should move according to theory.

The only other change noticed in regard to these planets is that reported by Mr. Douglas at the Lowell Observatory, Flagstaff, in 1897, in regard to spots on the surface of the third and fourth satellites of the planet Jupiter. His observations showed that these satellites rotated in the same time they made one revolution around the planet.

In the chapter on comets we find that the comet family of Jupiter has grown to the number of 27 from 16, as reported in the former edition. Next, in new matter, comes a brief history of the wonderful Brooks' Comet 1889 V, for a time known as the Lexell-Brooks comet. The history of the changes in the orbit of that comet reads like a fairy tale, although learned by the thoughtful and patient researches of such mathematicians as Laplace. Leverrier and our own Chandler. Following this is the report of that erratic visitor of 1892-3, known as Holmes's comet which in many ways was remarkable. Its singular behavior in change of brightness and size is yet without explanation. The paragragh on the photography of comets and the illustration of the Rordame comet, as photographed by W. J. Hussey at the Lick Observatory are useful additions in the new text.

The chapter on the stars contains accounts on the new stars of Auriga, 1891, of Carina, 1893, of Norma, 1895. The researches on the first are truly wonderful. If Vogel is right the spectroscope showed two great masses in motion whose relative velocity must have exceeded 550 miles per second. The last two were found on photographic plates at Harvard College Observatory which were taken at the station, Arequipa, in South America.

The matter under the head of variable stars is considerably changed and some new added especially relating to the eclipse theory and the aid of photography in detecting variables; but in double stars the spectroscope by the aid of photography has revealed even more wonderful results. Nearly two pages of intensely interesting matter is added which marks recent progress in this particular. In this connection we are glad to see that Dr. T. J. J. See's important work on the evolution of binary systems has merited recognition even in a text-book on the elements of astronomy.

The question of the motion of the nebulæ has been at last definitely solved in relation to some of them. It had so long baffled the sturdy attempts of skilled observers, that efforts were few latterly, in this direction, until Professor Keeler, while at Lick Observatory, began the study of the bright nebulæ with a spectroscope of high dispersive power. By such an instrument he was able to detect and measure the motion of some of them in the line of sight. This fact of motion or not, so long sought, is now known and it is also probable that the velocity of their motion is of the same order as that of the stars, the nebulæ so far observed giving results ranging from zero to forty miles per second, in the line of sight, some approaching and some receding. The great nebula of Orion is receding at the rate of about ten miles per second.

A few changes are noticed in the appendix and the tables to bring them to date. But one of the best things in the new book is the synopsis for review and examination found near the close of the volume. This consists of 100 consecutively numbered paragraphs which, in condensed form, present a kind of scheme of the entire contents of the book. It ought easily to be very helpful to student and teacher when it is the purpose of each to do faithful and finished work in the study of the elements of astronomy

In our hasty reading of this revision we have noticed but one error, and that is on page 331 line 3 from the bottom, 459 should be 429.